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Article

Energy Consumption Reduction by High Solar Reflective Paint

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Abstract. High solar reflective paint has been widely used nowadays. It is claimed that it can substantially reduce heat gain through building envelope and energy consumption of houses. This study investigated energy saving from using high solar reflective paint compared with conventional paint. The chosen color tone was dark brown. Actual energy consumption was measured from two houses. One house was painted with high solar reflective paint. The other one was painted with conventional paint. Both houses were identical: 4 m wide x 6 m long x 3.16 m high with 24 m^2 floor area. The houses were located in Samut Prakan, Thailand. From actual measurements during March and September 2019 which were in the hot and rainy seasons of Thailand, it was found that high solar reflective paint could reduce exterior surface temperature by as high as 8.1°C and save energy by 31.24% from decreasing cooling load due to less heat gain through the envelope. The energy simulation using the EnergyPlus software showed 32.69% saving which agreed well with the actual results.

Keywords: High solar reflective paint, surface temperature reduction, energy saving, actual measurement, energy simulation.

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1. Introduction

There are a lot of high solar reflective paints available in the market nowadays. They are claimed to be able to dramatically reflect heat from solar radiation falling onto outside surfaces of building envelope, reduce outside and inside surface temperature, and reduce cooling load of air conditioning systems. Building envelope absorbs heat from the sun as well as heat due to the temperature difference between outdoor and indoor spaces. Heat gain through the building envelope contributes up to 57% of total cooling load [1]. Around 56% of household electric consumption spent on air conditioning that has to deal with such cooling load [2].

There have been several studies regarding solar or heat reflective paints. A study using box-like building models in Shanghai, China found that heat reflective efficiency depended on location, season, and orientation of buildings. Different kinds of heat reflective coatings performed differently. They were found to be able to reduce inside and outside wall surface temperature from 4.7 to 20.0°C [3]. In warm and humid climate like Hangzhou, China, it was found that heat reflective insulation coating could reduce outside surface temperature of test boxes by 8.0 to 10.0°C [4]. An experimental house was constructed in Nanchang, Jiangsu, China which is classified as a hot and humid climate area. The model house was partitioned into two rooms. One room was painted outside with heat reflective coating whereas the other room was not painted. From the measurement during summer and winter, it was found that room temperature of the first room was lower by 4.32°C [5].

In Athens, Greece, which is in the Mediterranean zone, concrete plates were painted with many solar reflective coatings available in the market and their surface temperature was measured. Solar reflective coatings could reduce surface temperature by up to 4.0°C during the day and 2.0°C during the night [6]. There was a computer simulation study in Iran regarding heat reflective paints blended with insulating minerals. It was predicted that surface temperature could be decreased by 4.5°C and electric energy consumption could be saved by 17.0% [7].

In Khon Kaen, Thailand, box models painted with solar reflective and conventional paints were compared. Maximum temperature difference inside the boxes was measured to be 7.0°C [8]. Another study in Thailand was conducted by comparing thermal performance of two houses painted with solar reflective and general paints. It was found that the house with solar reflective paint had 4.0°C lower inside temperature and 7.0% energy saving [9]. In Dominican Republic which is considered as a hot and humid area the same as Thailand, a number of brick walls were constructed and coated with several types of paint. It was measured that solar reflective paint could reduce surface temperature by 4.4°C on the east surfaces and 7.8°C on the west surfaces [10].

In this study, two identical houses were built. One house was painted with high solar reflective paint while the other one was painted with conventional paint. Dark brown color was selected to see the effects of a so-called extreme case since dark color tone is known to absorb heat more than light color tone. Outside and inside surface temperature of both houses was measured. One split-type air conditioner was installed in each house and their energy consumption was measured to assess the energy saving. Energy consumption of the houses was also simulated by using the EnergyPlus software to estimate the energy saving potential.

2. Methodology

Two identical houses (4 m wide x 6 m long x 3.16 m high, 24 m^2 floor area) as shown in Fig. 1 were constructed. The building envelope was made of two layers of 9-mm gypsum boards. Dark brown color tone was chosen and considered as an extreme case since it is commonly known that dark tone absorbs substantially more heat than light tone. One house was painted with high solar reflective paint while the other house was painted with conventional paint. A 2.5-ton split-type air conditioner was installed in each house to compare energy consumption. Both houses were located in Samut Prakan, Thailand, which is an outskirt city of Bangkok. The experiment was carried out during March and September, 2019 which covered hot and rainy seasons of Thailand. The air conditioners were operated from 9 a.m. to 7 p.m. which was the period of interest for energy use consideration in this work. The total number of experimental days in hot season (March to May, 2019) and rainy season (June to September, 2019) was 56 and 95 days, respectively. Outside and inside surface temperature as well as energy consumption of both houses were recorded to verify temperature reduction and energy saving from the use of high solar reflective paint.

Thermocouples type K (±2.2°C accuracy) were used for temperature measurement. Graphtec Midi Logger 820 (±0.05% accuracy) was used for recording the data. Electric energy consumption was measured by Kepler KP-835 energy meter (±1.22% accuracy). Figure 2 shows the data logger and energy meter used in this study.

Fig. 1. Two identical experimental houses.

Fig. 2. Data logger and energy meter.

As it can be seen from Table 1, most of the past studies were conducted using light tone colors. On the contrary, this study intended to use dark brown color to verify how much the dark tone colors, generally known to absorb more solar radiation than light tone colors, would be able to reduce house temperature and save energy consumption. Optical properties of the paints used in this study were summarized in Table 2. It should be noticed that the reflectance in the range of infrared or "heat" of the high solar reflective paint is significantly higher (about 5 times) than that of the conventional paint.

Table 1. Key results from some previous studies.

Researchers	Year	Country	Temp. Reduction (°C)	Ref.
Synnefa et al.	2006	Greece	4.0	[6]
Shen et al.	2011	China	4.7	[3]
Guo et al.	2012	China	10.0	[4]
Chaiyosburana et al.	2013	Thailand	4.0	[9]
Chaiyakul	2013	Thailand	5.0	[8]
Azemati et al.	2013	Iran	4.5	[7]
Guo et al.	2017	China	4.3	[5]
Puesan and Mestre	2017	Dominican	7.8	[10]

Table 2. Optical properties of high solar reflective and conventional paints.

Paint Product	Solar Reflectance (%)		
	UV Range	Visible Range	Infrared Range
High solar reflective paint	8.3	14.6	60.0
Conventional paint	8.0	13.5	12.7

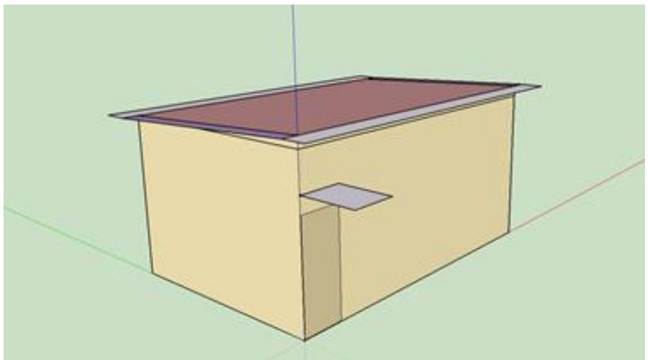


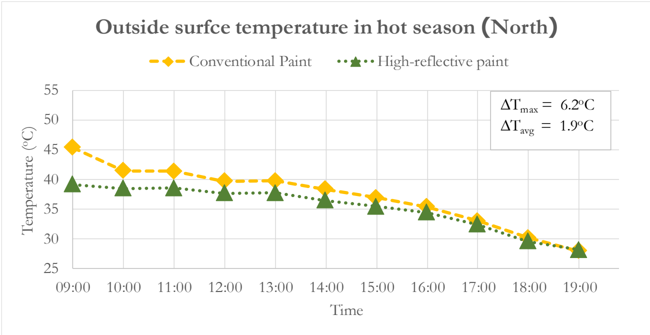
Fig. 3. EnergyPlus model of experimental houses.

Building energy simulation by EnergyPlus software (2 to 7% accuracy) was also performed to compare the energy saving with the actual data [11-17]. The geographical structure of the houses as illustrated in Fig. 3 was created in the SketchUp software first. The information of the houses including thermal properties of materials, construction layers, lighting systems, air conditioning systems, and operating schedules were input through the OpenStudio software, which may be seen as the interface of the EnergyPlus software. Then, energy simulations were run covering the same period as the actual experiment. It should be noted that the paint should be input as an explicit layer of construction under the category of "No Mass Material" in the EnergyPlus software. It should not be input by changing the properties of the outside surface of the envelope to be those of the paint. Otherwise, the simulation results would be considerably unrealistic [18]. The weather data used in the simulations was the "Typical Meteorological Datasets" or TMDs of Bangkok derived from the actual recorded data during 2001 and 2015 [19].

3. Results and Discussion

3.1. Surface Temperature Reduction

The experimental results showed that the high solar reflective paint could reduce outside and inside surface temperature compared with the conventional paint. Figure 4 shows the average outside surface temperature of both houses during March and May, 2019 which was the hot season of Thailand. The maximum temperature difference of outside surfaces of 6.2°C occurred on the north walls. The average outside surface temperature difference during the hot season was evaluated to be 2.2°C. Figure 5 shows the average inside surface temperature of both houses during the hot season. The maximum temperature difference of inside surfaces of 3.7°C took place on the west walls. The average inside surface temperature difference was calculated to be 2.0°C. The results agreed well with the previous studies summarized in Table 2 [3-10].



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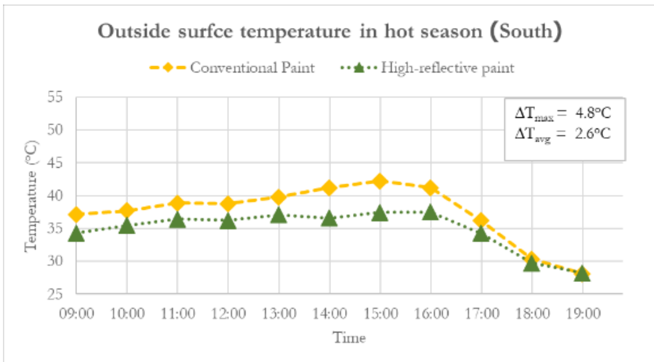

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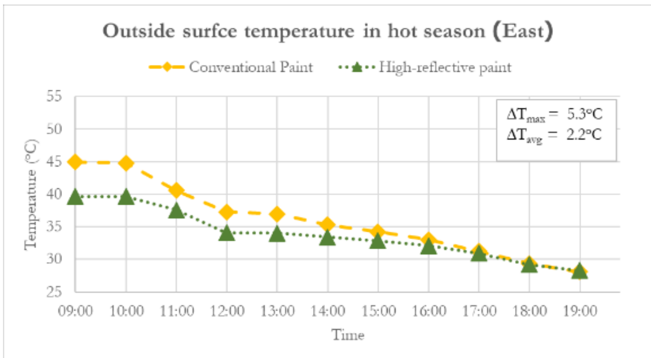

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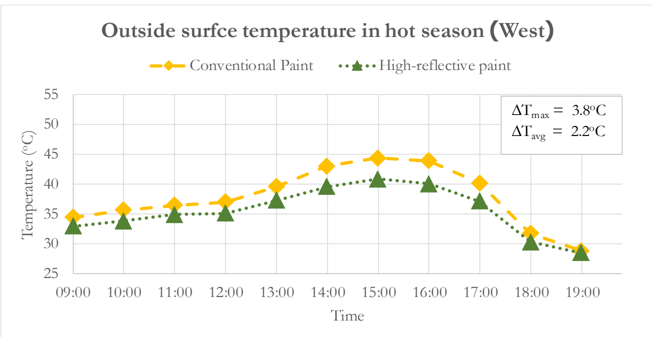

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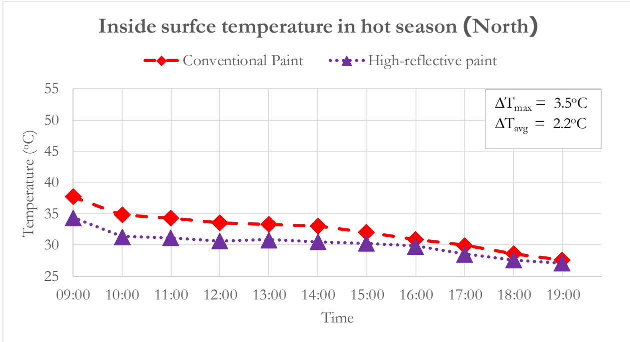
Fig. 4. Average outside surface temperature of both houses in hot season (March to May, 2019).



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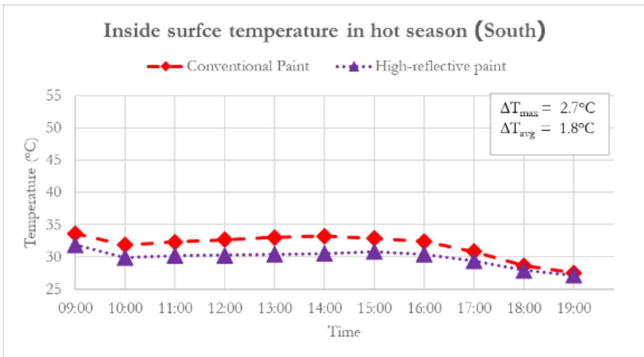

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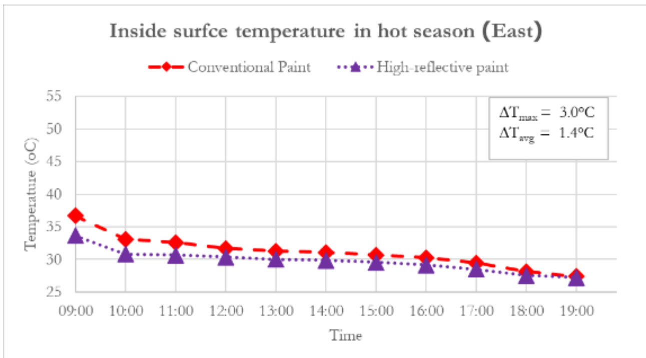

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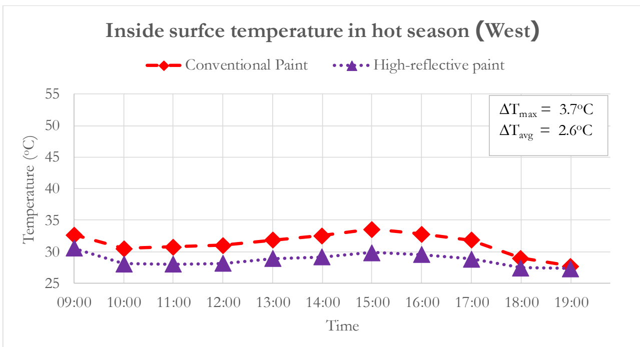

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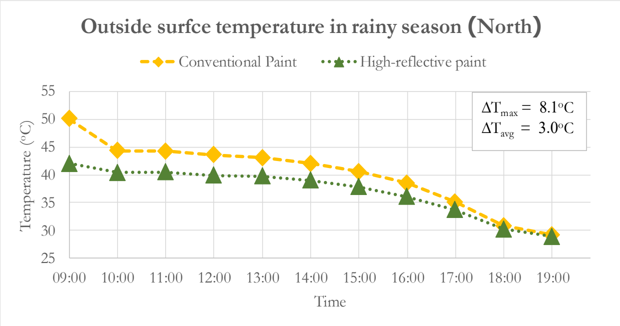
Fig. 5. Average inside surface temperature of both houses in hot season (March to May, 2019).



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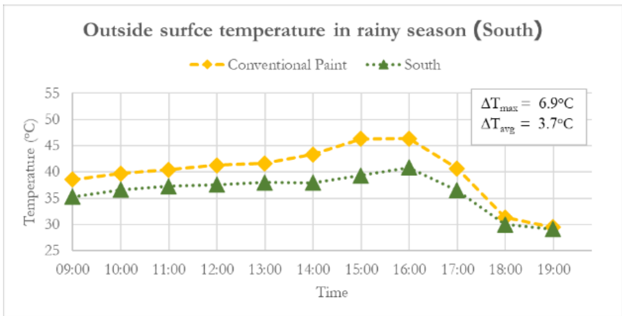

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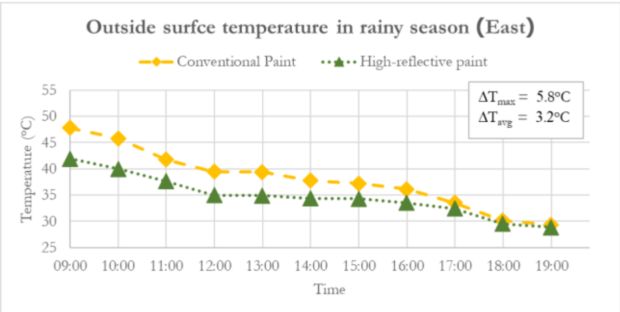

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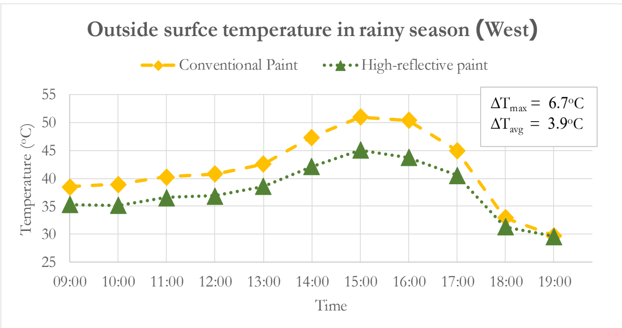

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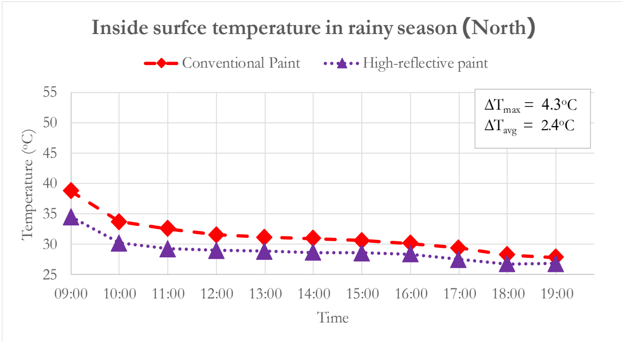
Fig. 6. Average outside surface temperature of both houses in rainy season (June to September, 2019).

Figure 6 expresses the average outside surface temperature of the two houses during June and September, 2019 which was the rainy season of Thailand. The maximum temperature difference of outside surfaces of 8.1˚C happened on the north walls. The average outside surface temperature difference during the rainy season was 3.5˚C. Figure 7 shows the average inside surface temperature of both houses during the rainy season. The maximum temperature difference of inside surfaces of 4.3˚C occurred on the north walls. The average inside surface temperature difference was 2.5˚C. The results also agreed well with the past studies [3-10].



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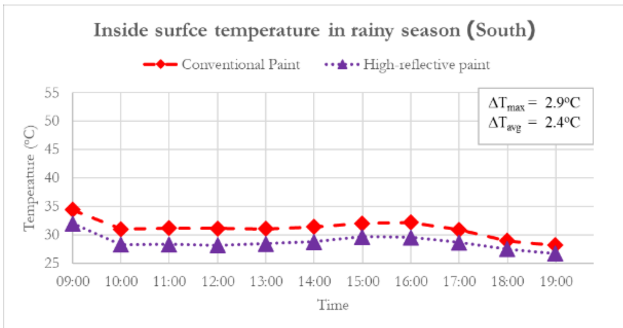

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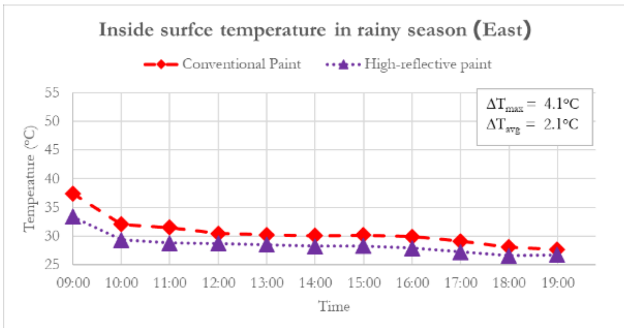

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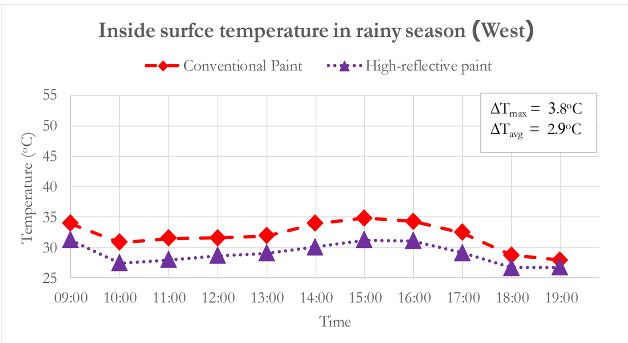

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Fig. 7. Average inside surface temperature of both houses in rainy season (June to September, 2019).

3.2 Energy Saving

Figure 8 shows the actual energy consumption of the two houses. It can be seen that the house with high solar reflective paint consumed substantially less energy compared with the house with conventional paint. The maximum energy saving of 32.73% took place in March 2019 while the average energy saving was found to be 31.24%.

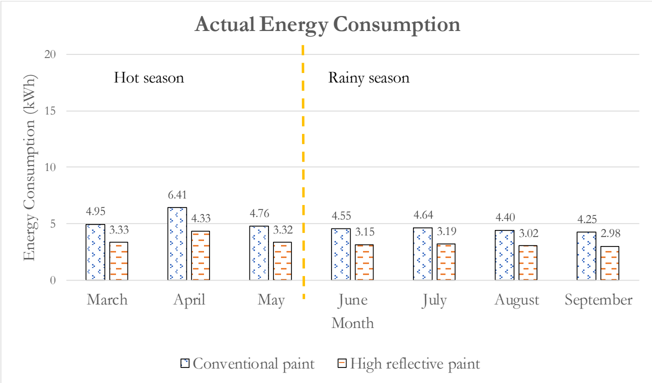

Fig. 8. Actual energy consumption of both houses.

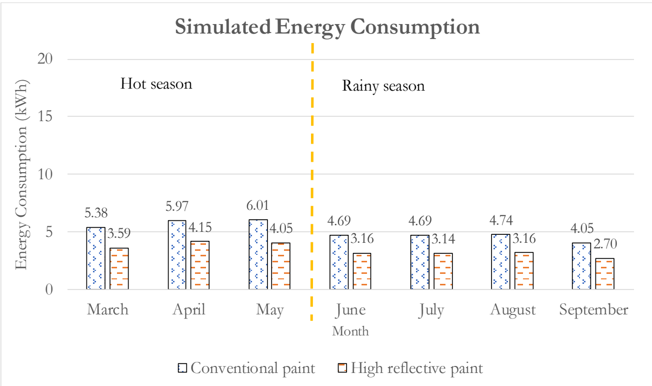

Fig. 9. Simulated energy consumption of both houses.

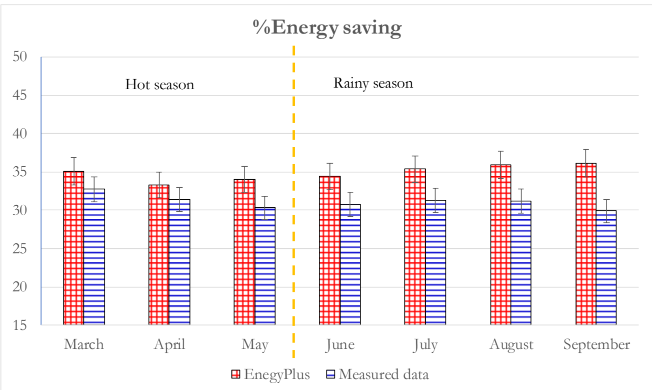

Fig. 10. Comparison of energy saving from actual measurements and computer simulations.

Figure 9 shows the simulated energy consumption of both houses during the same period as the actual measurements. The energy consumption obtained from the simulations was not significantly different from the energy consumption retrieved from the actual measurements (RMSD = 6.88%). It was found that the house with the high solar reflective paint saved energy up to the maximum of 33.34% whereas the average saving was 32.69%. The simulations using the EnergyPlus software yielded the similar results to the actual experiment. Comparison of energy saving from the actual measurements and the simulations was expressed in Fig. 10.

4. Conclusion

This paper reported the comparison of envelope surface temperature and energy consumption between two identical houses painted outside with dark tone, high solar reflective paint and conventional paint. It was found that the high solar reflective paint could reduce outside surface temperature by up to the maximum of 8.1˚C while the average outside temperature reduction was 3.5˚C. The maximum inside surface temperature reduction was 4.3˚C whereas the average inside surface temperature reduction was 2.5˚C. The findings agreed well with past studies. The high solar reflective paint could actually save the energy consumption by 31.24%. The energy simulations using the EnergyPlus software provided the similar results to the actual measurements.

Acknowledgement

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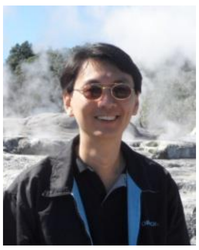

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Peeranut Prakulpawong was born in Bangkok, Thailand in 1992. He received the B.Sc. in Chemistry Science from Mahidol University in 2013 and M.Sc. in Polymer Science and Technology from Mahidol University in 2017. From 2015 to 2016, he was a Research Assistant Student with the Siam Cement Group and DT Lab Group (from Mahidol University). Since 2018, he has been a innovation chemist with Beger Co., Ltd. He is the author of 2 papers. His research interests include oil removal materials, thermal insulation coating, reflective coating, and innovative coating.