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A Thermal Assessment of Residential Models

A Study of the Model Made of Fibre, Cement and Wood

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Abstract | Sun heat in Thailand is coming stronger every year, with record breaking temperatures. It is important to learn ability of thermal properties of house materials (insulation). Therefore three replica simple house models have been built, one model with wood and the other two with fiber cement planks for ceiling, flooring, and walling. Due to a density of wood about half of fiber cement plank, wood thickness was selected to be double of fiber cement plank. Roof of all replica models is made of non-asbestos fiber cement smart board. Under a rather calm weather during late April to early May 2017, these models were used to observe hourly temperatures inside the house during 08.00-16.00. All these three models were placed in Thammasat University Rangsit Campus (Pathumtani Province). The point to place the models was selected such that the taller building casted a shadow on all the models for 15.00 hours and after. This was to block sunlight and see how wood and fiber cement planks be able to release the heat to its surrounding. This experiment found that the model with wood, temperatures inside all the rooms were lower than that of the other two models with fiber cement planks. After under the shadow of the tall building, the model with wood room temperatures was cooled off at a slower rate compared to the other two replica models.

Keywords | urban sustainability; replica simple house.

Introduction | Solar thermal heat causes discomforts to people in participating in their daily various activities. During the summertime, Thailand experiences its hottest period. In their homes or offices, it makes people turn on their fans and air conditionings in order to take away the heat. This causes high electricity uses and thus high electric bill. As a result, peaked power consumption goes higher every year (Fig. 1). For 2017, peak temperatures for central of Thailand were expected to be around the end of April to Early May.

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Tropical and Thailand's Climate with Summer Peaked Electricity Consumptions

According to Köppen climate classification, a tropical (non-arid) climate has twelve months mean temperatures higher than 18 °C. Tropical climates have small variations of the solar angle, thus hot weather can be observed all year round with rather constant temperatures (R-value, 2017).
The Kingdom of Thailand situates at the center of the Indo-chinese peninsula in Southeast Asia. Geographic coordinates are about 15° 00’ N, 100° 00’ E. With high humidity, Thailand has mean annual temperatures around 28°C. Observed climate is rainy, warm, cloudy with southwest monsoon (mid-May to September); dry, cool with northeast monsoon

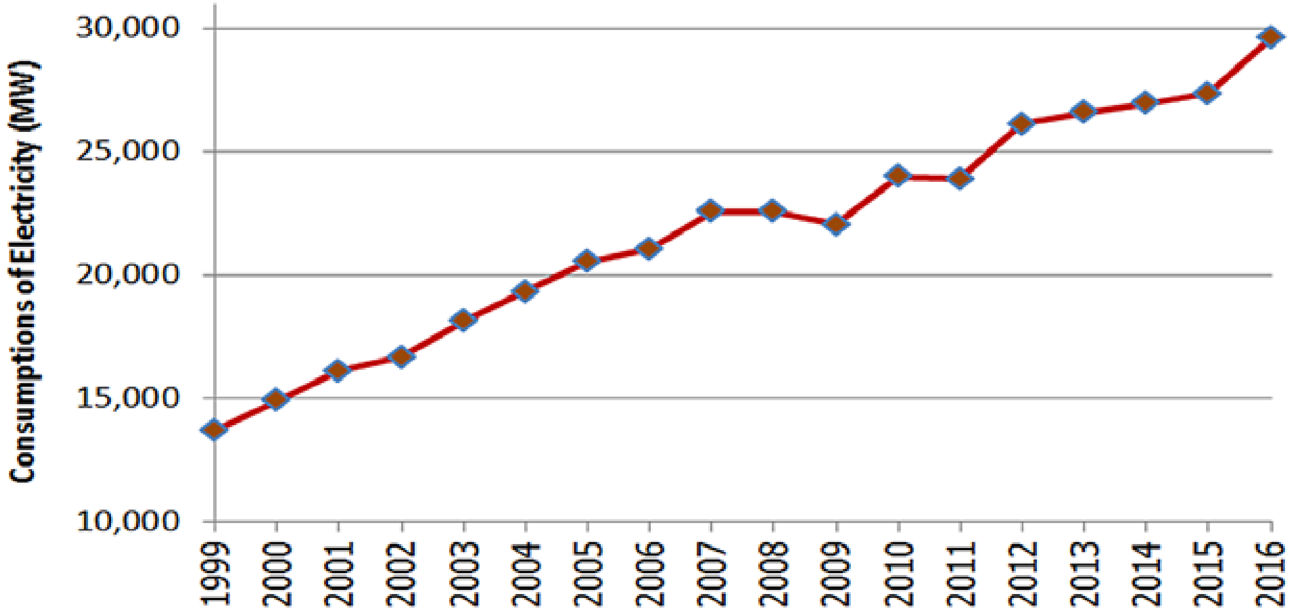


Fig. 1: Peak yearly record of electric consumption in Thailand . Source: m EGAT, 2017.

(November to mid-March); southern isthmus always hot and humid (CIA, 2017). Table 1 shows a record of breaking temperatures in Thailand during 2016.

Heat Index (HI)

The heat index (HI), or humiture, combines air temperature and relative humidity (RH), in shaded areas. This index attempts to determine "felt air temperature" or "apparent temperature", the human-perceived equivalent temperature in the shade. For extreme caution (HI 32–41°C), heat-related illness (heat cramps and heat exhaustion) are possible and may encounter heat stroke as a result of continued activities. Effect of danger HI (41–54°C) is very likely to cause heat cramps, if not treated, leading to heat exhaustion and then heat stroke (Heat Index, 2017; NIH, 2015). Hourly weather observations for Don Mueang weather station are summarized in Table 2. Note that Don Mueang weather station is about 10km from Thammasat University Rangsit Campus.

Literature Review

Three and a half decade ago, a national field survey of house temperatures in the UK was conducted in regards to energy conservation measures and thermal comfort (Hunt & Gidman, 1982). Bălan, Cooper, Chao, Stan & Donca (2011) studied a way to optimize HVAC (Heating, Ventilation and Air Conditioning) systems used for heating or cooling buildings. The collected simulation data was used to identify the parameters of a thermal model of the house in which the control of the thermal system was performed using a model based predictive control. Bakhlah & Hassan (2012a) studied the effect of roof color on indoor house temperatures in case of Hadhramout, Yemen. After painting the roof with white color, the results obtained show that white color can reduce the indoor air temperatures up to 2.3°C. Bakhlah & Hassan (2012b) investigated the indoor air temperature conditions of prayer hall of Al-Malik Khalid mosque, Penang, Malaysia, during the occurrence of the sun path towards qibla direction. Sanusi Shao & Ibrahim (2013) investigated Earth Pipe Cooling Technology as a passive ground cooling system for low energy buildings in Malaysia, by burying polyethylene pipes at 1 m underground. With a concept that ground is a heat sink to produce cooler air, temperature drops between pipe inlet and outlet were in a range from 6.4°C and 6.9°C depending on the season of the year.

Many researches use façade to prevent sun's heat/sunlight penetration on house, e.g. Hassan & Bakhlah, (2013a, 2013b) studied effects of shading on the front facade of modern terraced houses in Malaysia.

Even though people can opt to open windows to take natural ventilation, most people like their windows closed, due to environmental issues such as dust/pollens coming with the air flow, as well as they require some kind of privacy. They will have to turn on their air conditioner consuming high energy and increased carbon-dioxide emissions. Walling materials become an important insulation to prevent heat from outside, where this study is about.

Study method

House Plan

A simple one-story house has been selected, with two to three people living in. Floor plan dimensions are 9.5x8 m^2 comprising a bedroom (4x4 m^2), a living room (4x4 m^2), a kitchen

Table 1: Record-breaking temperatures in Thailand April 28, 2016. Source: authors.

Part	Province	Temp. °C
North	Mae Hong Son	44.6
Northeast	Surin	42.7
Central	Nakornsawan	43.3
East	Srakaew	41.4
South	Nakornsrithammarat	40.5
Bangkok and suburbs	Pathumtani	39.0

Table 2: Hourly Weather Observations of Don Mueang Station for May 1, 2017. Source: WU, 2017.

Time (+07)	Temp °C	Heat Index °C	Dew Point °C	RH	Pressure hPa	Visibility km	Wind Direction	Wind Speed	Conditions
8:00 AM	30.0	38.8	27.0	%84	1012	10.0	Calm	Calm	Partly Cloudy
8:30 AM	31.0	40.5	27.0	%79	1012	10.0	South	5.6 km/h / 1.5 m/s	Partly Cloudy
9:00 AM	32.0	40.4	26.0	%70	1012	10.0	South	9.3 km/h / 2.6 m/s	Partly Cloudy
9:30 AM	33.0	41.8	26.0	%66	1012	10.0	South	9.3 km/h / 2.6 m/s	Partly Cloudy
10:00 AM	34.0	45.3	27.0	%67	1012	10.0	South	13.0 km/h / 3.6 m/s	Partly Cloudy
10:30 AM	33.0	40.6	25.0	%63	1012	10.0	West	11.1 km/h / 3.1 m/s	Partly Cloudy
11:00 AM	34.0	41.8	25.0	%59	1012	10.0	SW	7.4 km/h / 2.1 m/s	Partly Cloudy
11:30 AM	34.0	45.3	27.0	%67	1011	10.0	WSW	11.1 km/h / 3.1 m/s	Scattered Clouds
12:00 PM	35.0	46.5	27.0	%63	1011	10.0	West	14.8 km/h / 4.1 m/s	Scattered Clouds
12:30 PM	34.0	43.5	26.0	%63	1011	10.0	WSW	5.6 km/h / 1.5 m/s	Scattered Clouds
1:00 PM	34.0	43.5	26.0	%63	1010	10.0	SSW	14.8 km/h / 4.1 m/s	Scattered Clouds
1:30 PM	35.0	44.6	26.0	%59	1009	10.0	SSW	16.7 km/h / 4.6 m/s	Scattered Clouds
2:00 PM	34.0	43.5	26.0	%63	1009	10.0	SE	18.5 km/h / 5.1 m/s	Partly Cloudy
2:30 PM	35.0	43.2	25.0	%56	1008	10.0	SSE	11.1 km/h / 3.1 m/s	Partly Cloudy
3:00 PM	37.0	47.4	26.0	%53	1008	10.0	WSW	7.4 km/h / 2.1 m/s	Partly Cloudy
3:30 PM	36.0	44.5	25.0	%53	1007	10.0	SSW	13.0 km/h / 3.6 m/s	Partly Cloudy
4:00 PM	36.0	43.1	24.0	%50	1007	10.0	SSW	9.3 km/h / 2.6 m/s	Partly Cloudy
Key to colors				= Extreme caution				= Danger	

Note: The half-winds: north-northeast (NNE), east-northeast (ENE), east-southeast (ESE), south-southeast (SSE), south-southwest (SSW), west-southwest (WSW), west-northwest (WNW) and north-northwest (NNW).

room (6.1x3 m²), and a restroom (1.9x3 m²). Ceiling height (floor to ceiling) is 3m. There is a sufficient porch area for persons to recess in front of the building (Fig. 2).

Scale Replica House Models

House models are used to represent the real house while maintains dimension aspects of the models. For room temperature monitoring, absolute values of the original material are not preserved. These housing models enable to observe temperatures inside the houses that each uses different materials to make ceiling, flooring, and walling without examining the full-scale house itself. Various scales of the replica houses/objects can be found, depending on studied objectives and respective conditions.

This study built three house models. For the sake of convenient, kitchen room and restroom are not separated, detailed in Figure 3. The first house model (model#W1) uses wood planks for ceiling, flooring, and walling, while the other two models (model#CF1 and #CF2) use fiber cement planks. All house models have the same scale of 1:9.5 of a real house (i.e., each dimension of the house models is 1/9.5 that of the real house). Model floor plan dimensions are 1x0.84 m² (com-

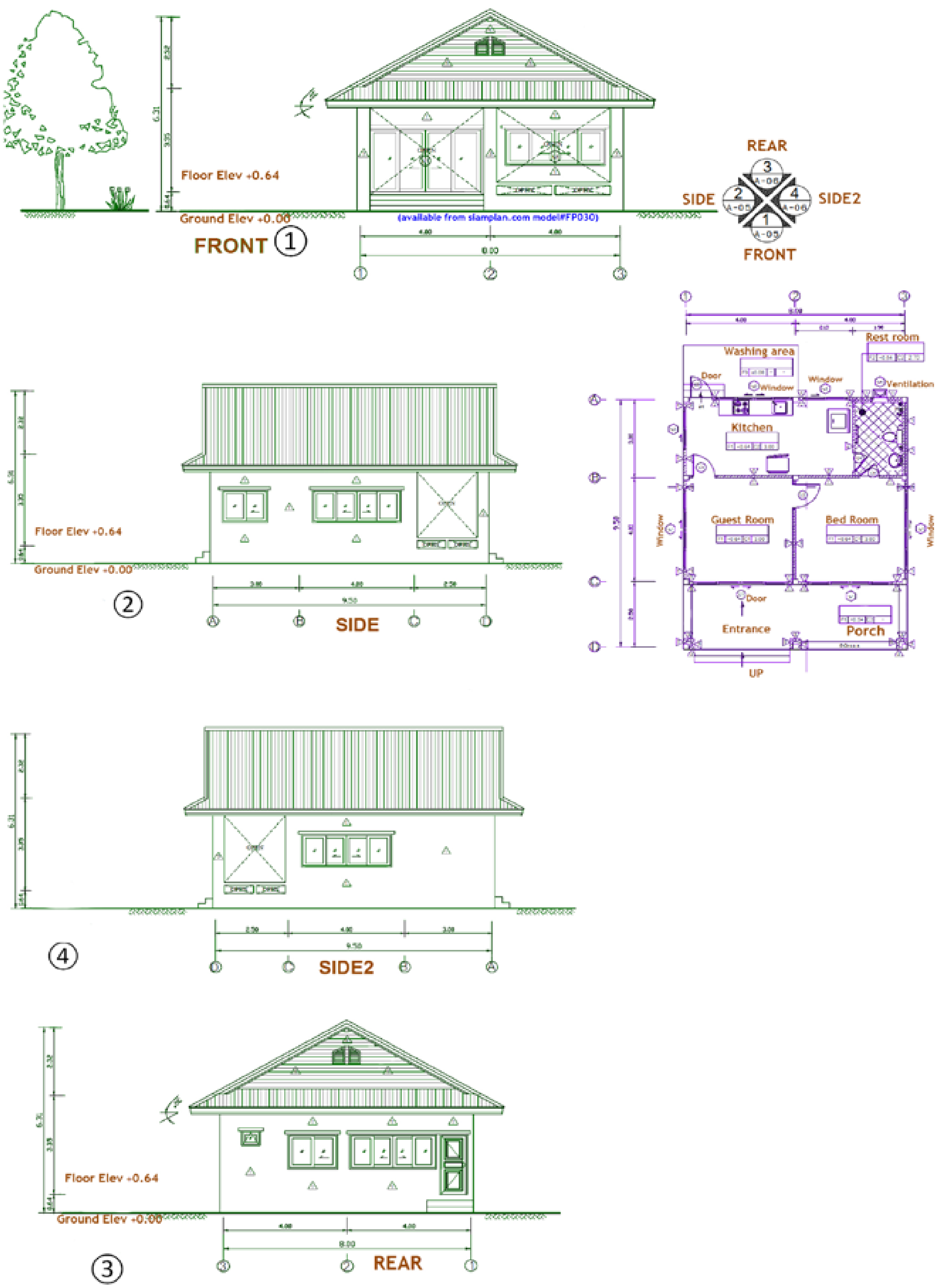


Fig. 2: A simple house used in this study with floor plan. Source:www.siamplan.com model#FP030.

pared to the real house floor plan 9.5x8 m^2) and height 0.35m (compared to the real house height 3m); (Fig. 3). All model rooms are fully encapsulated (airtight) that only thermometers wires can go through to the room. Total nine digital thermometers are used, one per room. Thus temperatures from all rooms can be simultaneous observed. Table 3 gives detail of materials used for ceiling, flooring, and walling for each model. Important technical information of model materials is given in Table 4.

Fiber Cement Plank

Being a composite material, fiber cement is a mix of sand, cement and cellulose fibers and then made into planks. Fiber cement planks are termite and bugs resistance, decay and water resistance and weather resistance, with fireproof properties. Comparing to wood, fiber cement is rather flexible with low shrinkage. Models #CF1 and #CF2 use different brands of cement fiber planks for the ceiling, flooring, and walling. These cement fiber planks have Green Label/Carbon Label/ Carbon Reduction.

Wood Plank

From model#W1, wood planks are from the mixed deciduous tropical forest (a mixed of a wide range of hardwood to softwood trees, with colors varied from lutescent to maroon). As cement is twice denser than wood (Table 4), therefore the thickness of wood planks used in this study is set to double of fiber cement plank thickness. Each wood plank is 15mm thickness x 75 mm width.

Roof of House Model

The roof of replica models is made of non-asbestos fiber cement smart board, a composite of Portland cement, silica and special cellulose fiber. With special production, the board gains strength, durability, and elasticity. Being fiber cement material, the board is water resistance and non-decay with termite resistance.

Thermal Resistance (R-value)

To measure thermal resistance, R-value is a term/indicator used to indicate the ability of insulation to prevent heat transfer. The higher the R-value, the better the insulation material to prevent heat transfer. From Table 4, it can be noticed that wood plank used in the house model is about 10times higher than fiber cement plank (Fig. 4).

Exposure to the Sun

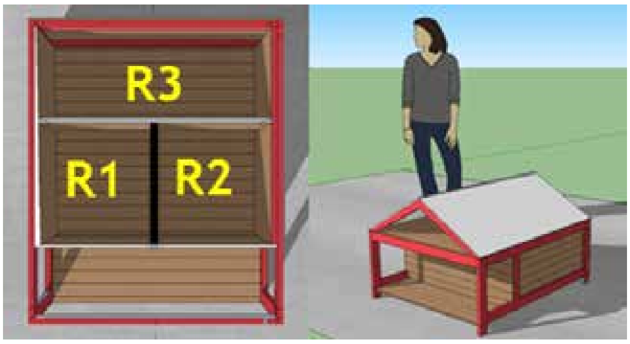
All three housing models were placed outdoor under the sun, at Thammasat University Rangsit Campus (Lat 14.069589, Long 100.606768); (Fig. 5). Front of all models faced to the East. Each model room temperature is hourly read and recorded in degrees Celsius.

Result and Discussion

For each room of each replica model, the hourly observed temperatures are plotted. Figure 6 and 7 show the each room hourly temperatures for May 1, 2017, and average temperatures during 28 April - May 4, 2017.

From Figures 6 and 7 rooms R1 and R2, we can see that models CF1 and CF2 have higher temperatures compared to model W1, about 2-3°C depending on the hour of the day. The rooms are at their hottest during 14.00 to 15.00. It can readily be seen that room R3 which is in a back position, behind rooms R1 and R2, has higher temperatures 0.5-3°C compared to rooms R1 and R2.

From 15.00 hour and after, the taller building cast a shadow on all the models. This aimed to block sunlight and observe how house model with wood and fiber cement planks be able to cool off in shadow and release the heat to its surroundings. From all temperature plots, after under the shadow of the tall building, the model with wood room temperatures was cooled off at a slower rate compared to the other two replica models. For wood replica model, temperatures for all rooms seem to



R1 = Living Room R2 = Bed Room R3 = Combined Kitchen Room and Rest Room

Fig. 3: Drawing of the replica house model in Sketch Up®.Source: authors.

Table 3: Model ID and detail of ceiling, flooring and walling materials. Source: authors.

Model ID	Detail of ceiling, flooring, and walling material	
W1	Wood planks	15mm thickness x 75mm width
CF1	Cement fibre planks (brand A)	8mm thickness x 200mm width
CF2	Cement fibre planks (brand B)	8mm thickness x 150mm width

Table 4: Technical Information of model materials. Source: authors.

Technical Properties	Standard	W1	CF1	CF2
Physical Properties				
Thickness (mm)	ASTM C1185/ TIS 2540-1427	1±	0.50±	0.50±
Density (kg/cm3)		750-530	≥1200	50±1300
Moisture content		%15-10	≤%17	≤%15
Water Absorption			≤%37	≤%35
Thermal conductivity, K (Watt/m Kelvin)	ASTM C518--10	0.03-0.06	0.127	0.125
Thermal Resistance, R-value (Watt/m2 Kelvin)		0.68-0.76	0.075	0.074
pH	ISO 10390	4-6	7-8	7-8
Fire Resistance	BS 476 Part22	-	78min	75min
Durability Properties				
Freeze-Thaw Resistance	ISO 9384 1991(E)	-	Pass	Pass
Warm water Resistance	ASTM C1185	-	Pass	Pass
Soak /Dry Resistance	ISO 8336 2009 (E)	-	Pass	Pass
Heat / Rain Resistance	ASTM C1185	-	Pass	Pass

Fig. 4: The replica wood house model with steel frame. Source: authors.

be lower outside temperatures almost until 11.00. However, under this airtight condition model, heat seems to trap longer even after under shadow of the taller building.

It can be observed from all plots until 10.00 for rooms R1 and R2, that temperatures are lower than outside temperatures. To help keep electric bills lower, air conditioner thermostat may-

Fig. 5: Solar heat exposures of three models. Source: authors.

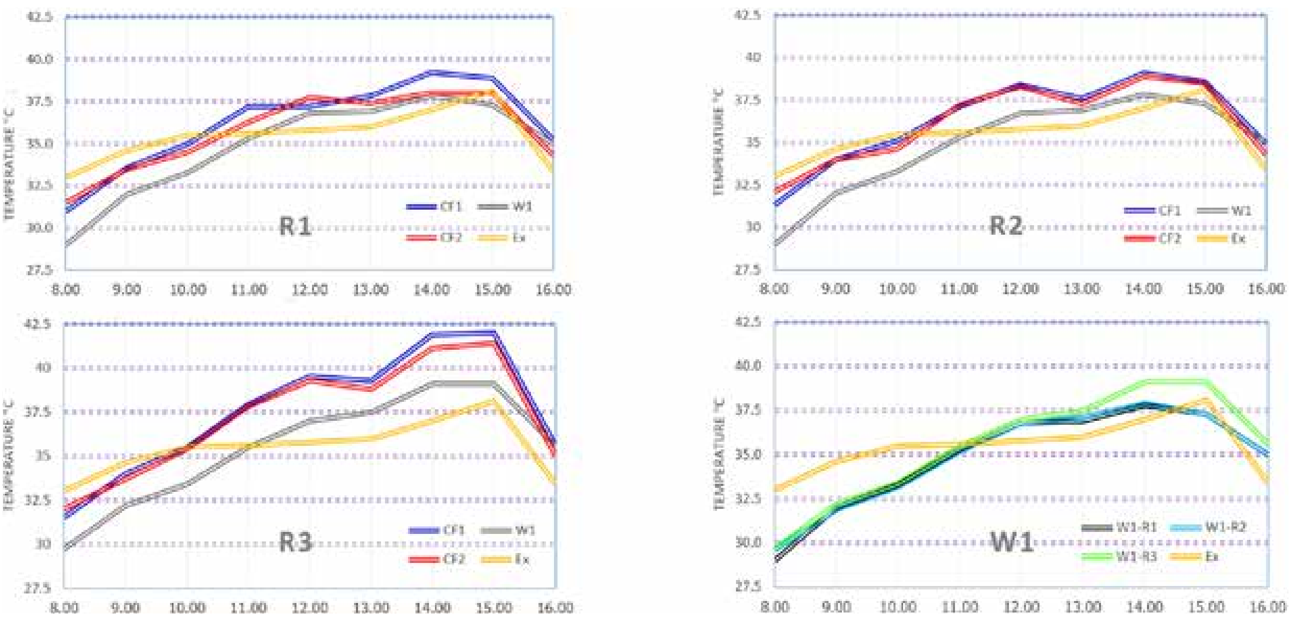


Fig. 6: Observed temperatures for May 1, 2017. Source: authors.

be set a few degrees higher and air conditioners may be turned on during this time (depending also on relative humidity (RH)/ and felt air temperature (i.e. heat index (HI) value)).

Conclusion

This study presented the experimental result of hourly observed temperatures of three replica simple house models using wood and fiber cement planks for the ceiling, flooring, and walling. The aim was to see the ability of wood and fiber cement planks in using as insulation materials to the direct sun heat. Wood thickness was chosen to be double of fiber cement planks due to its density is only half of fiber cement planks' density. Under the sun heat, the model with wood, all the rooms' temperatures were lower than that of the other two models with fiber cement planks. After 15.00 shadow from a taller building casting all the housing models, it found that wood room temperatures were cooled off at a slower rate compared to the other two replica models. Wood has higher the R-value, thus the better the insulation material to prevent heat transfer.

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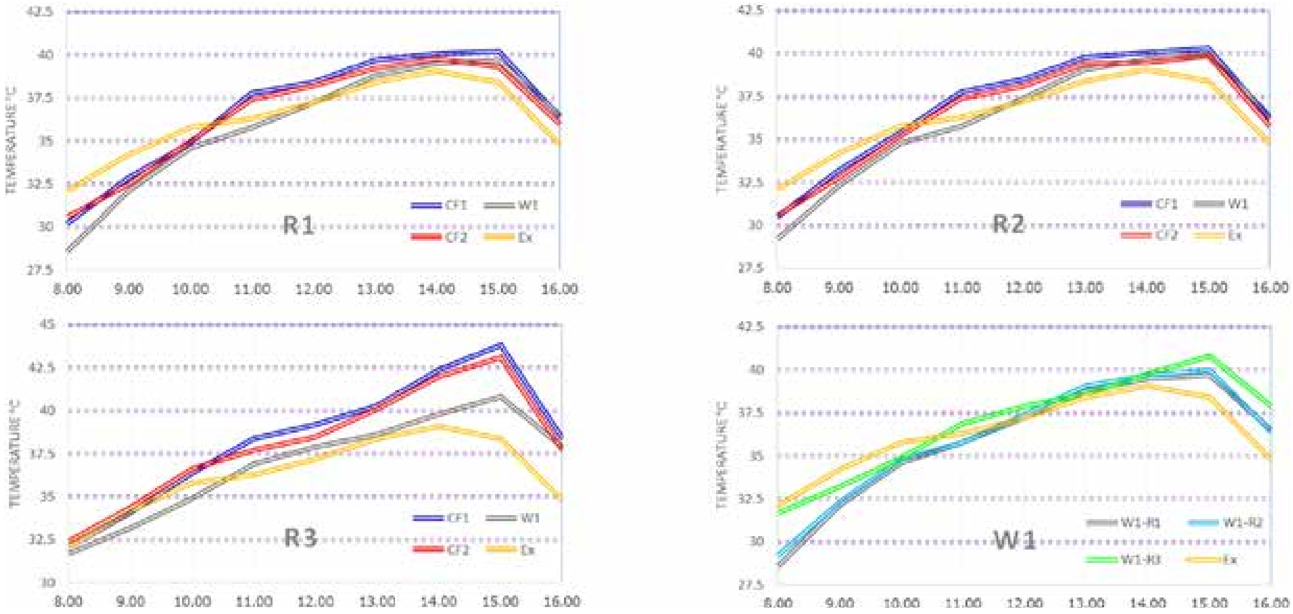

Fig. 7: Average observed temperatures for 28 April - May 4, 2017. Source: authors.

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