MANZAR, 10 (45): 18-25 / January 2019
DOI: 10.22034/manzar.2018.80492

Fundamental Study on Thermal Surface Analysis of Late Modern Styles' Apartments with Case Studies in Malaysia

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Abstract | This study discusses a comparative analysis of the thermal surface temperature of high-rise apartments designed with late modern styles in Malaysia. In Malaysia, apartments are divided to two categories namely midrise and highrise apartments. Highrise apartments are the residential buildings higher than five stories equipped with elevator whereas midrise apartments have no elevators with 3 to 5 stories' height. The results of this study will provide a thermal surface data of the apartment facades. The data enhances the level of sustainability awareness of the architectural styles on facade design to the tropical context. This thermal surface analysis will increase the design awareness of the architects who design the buildings in complying with their understanding to the climatic factors. Late modern design styles have a complex geometric design with ranging from simple to complex roof structures which have an emphasis on abstract geometric form in building design. In this study, two late modern design apartments are selected as the case studies. The location of these apartments is in Putrajaya, the latest new town built as an administrative city of Malaysia. The thermal surface data will be detected by a thermal device named Fluke Ti20 Infrared Camera. This camera will capture thermal images of the apartment facades. The analysis indicates that the facade design of both apartments does not achieve to curb solar radiation due to higher surface temperatures recorded in the on-field data compared to the highest average outdoor temperature at 32.4°C in Putrajaya. In conclusion in design of apartments shading and passive design are very important in tropical climate .

Keywords | Apartment, Thermal surface analysis, Late modern style.

Introduction | The aim of this research study is to contribute to thermal surface analysis on some apartment façade integrated with on-field study using thermal imager camera. It is the fundamental research study. The research findings will provide data which are helpful in guiding the architects and those who involved in the building envelope design to tackle solar radiation on the building facades (Arab & Hassan, 2015). With sufficient data, it will provide awareness to the designers to design building facades which reduce solar radiation. The design, therefore, will reduce energy consumption on the mechanical cooling system inside the buildings. By fostering exchange data on awareness of the apartment facade design, it will shed light on the importance of the building skin with minimum indoor heat gain , putting scientific know-how into practice (Prado & Ferreira, 2005) and (Arab, 2015).

Apartments provide house units for medium income family compared to condominium and flat house units for high and low income family (Hassan & Bakhlah, 2013), (Datcua, Ibosa, Candaua) and (Matteïb, 2005). Excellent facade design will

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Fig. 1: Apartments in Putrajaya.

help to hinder solar radiation which causes indoor heat gain problems to the occupants; therefore, the design can reduce electricity consumption on cooling cost (Al-Obaidi, Ismail, & Rahman, 2014 & Omer, 2014). It creates shades which block sunlight penetration to the indoor area and to the surface of apartment facade. Apartment house types are selected for the case study because it is one of the most popular house types built in the city able to provide high density house units per hectare. It is able to supply houses due to the high demand from the urban population in Malaysia which has a drastic increase from 34% in 1980, to 51% in 1990 and to 71% in 2010 (Department of Statistics Malaysia, 2015). The urban population in this country has a similar trend to the increase of the world's urban population from 38% in 1976 to 71% in 2008 (United Nations, 2010). In summary, this research will create a research design as follows:

• To measure the intensity of solar radiation (luminescence) level to the apartment facade
• Using on-field tools to measure thermal surface
• Guide to optimal design to tackle solar radiation to the building façades
• To provide data on thermal behaviour of the existing building envelope

In a tropical region like Malaysia, apartment facade design to prevent from solar radiation is crucial. Apartment facade exposed to direct sunlight causes the problem of solar radiation to the indoor area and facade's surface temperature (Omer, 2008). The sun energy will radiate the heat from outside wall transmitted into the interior of the house. It generates heat gains inside the house which create heat gain to the room air temperature, which causes the uncomfortable thermal condition to the occupants (Cena & Clark, 1978). The problem is that most apartment buildings have poor facade design with sun shading elements (Arab & Hassan, 2015). Most medium income people do not afford to install air conditional system in all rooms in their apartment and to pay high electric bills. The sun shading elements determine the intensity level of solar radiation striking on various surfaces of apartment facades (Hassan & Arab, 2014).

THE CASE STUDIES

There are two apartments in Putrajaya selected for the case study. Apartments in Putrajaya is selected for the case study. The main reason is that Putrajaya is the latest city built in Malaysia served as the federal administrative centre since 1999 (Moser, 2009). It is the showcase of the present apartment architectural styles leading to the future direction (Hassan, Arab & Ismail, 2015). Putrajaya is built based on a pre-planned masterplan to relocate the government servants to live in this new town under decentralised programme to tackle population overcrowding in Kuala Lumpur (Ariffini, 2003). All the projects are built by Malaysian companies. The average temperature (day and night) in Putrajaya is 27.1°C. The daytime's highest average temperature is in March with 32.4°C while the lowest temperature is 31.0°C in December with a difference of 1.4°C (Climate Data for Cities Worldwide, 2016).

The first case study is Apartment 17 Block A at P17 Street while the second case study is Apartment 18R8 at P18 Street (Government Officer Apartment). Apartment 17 as the Case Study X has a height of 17 storeys while Apartment 18R8 as the Case Study Y has 12 storeys' height. The main criterion for the selection is that both apartments were built in the 2010s. The other criterion is, both apartments have their west facade facing relatively perpendicular to the sun-path. Apartment 17 (Fig. 1) has a typical building design of late modern architectural style which explores the early idea of neo-minimalist style. The design rediscovers a value extreme simplicity in the design style, limiting to fundamental functions of architectural works without adhering ornamental motives. The design visually adores aesthetics with every element with multiple functions and purposes. It conveys Mies van der Rohe's phrase namely "less is more" towards simple design character, plan and elevation with grid layout, and dominant white colour (Cohen, 2007). Apartment 18R8 (Fig. 2) has similar design character with an impression of minimalist approach. The only difference is that the design style has an integration of simple traditional design with long roof structures.

Fig. 2: The Case Study X (left, Apartment 17 Block A at P17 Street as the Case Study X) and Y (right, Apartment 18R8 at P18 Street as the Case Study Y). Source: earth.google.com.

RESEARCH DESIGN

The scope of this research design consists of 2 parts namely research survey and analysis. The research survey will be conducted on-fields at the case studied apartments. It will collect surface thermal temperature of the apartment facades using thermal imager device called Fluke Ti20 which is a camera with a thermal surface detector. The on-field survey will only measure the surface temperature of the west facade of the apartments when the evening sun will directly cast sunlight to the facades. Both apartment facades have relatively perpendicular to the evening sun-path; as a result, these facades will be able to be fairly investigated for the comparative analysis. The measurement will be taken at hourly intervals from 1.00 pm to 6.00 pm. Fluke Ti20 will produce a series of digital surface temperature's photo images detected using an infrared lens which indicates the amount of heat casted at the surface's facades. There is a grid reference as an indicator to make it easily analysed by the researchers (Bezbabicheva, Bilchenko, & Kyslov, 2010).

To gain results of the analysis, thermal image photos were snapped using the Fluke Ti20 Camera at the facades of the case studies at a distance of 50 m snapped to the facade at human eye level. The thermal photos as mentioned above were taken hourly from 1:00 pm to 6:00 pm. The thermal photos will be taken limited to these hours due to the late evening weather conditions in the month of August at Putrajaya which has always cloudy sky and rain. The other limitation of this study is that the distance between Case Study X and Y is about 2.5 km apart to each other. With 4 traffic light and the distance, the researcher took about 10 minutes to reach from the Case Study X to Y before he was able to snap a digital photo of surface temperature.

Selected points of the surface temperature at the apartment façades were determined to use for comparative analysis. These selected points were made based on the coordinates on the grid layout from the camera thermal images as illustrated in Figure 3. The area of the grid points selected is slight below the apartment roof. The comparisons will be done based on coordinates of the selected point basis between the Case Study X and Y namely A1-3, B1-3, C1-3 and D1-3 series as well as the average of the selected points.

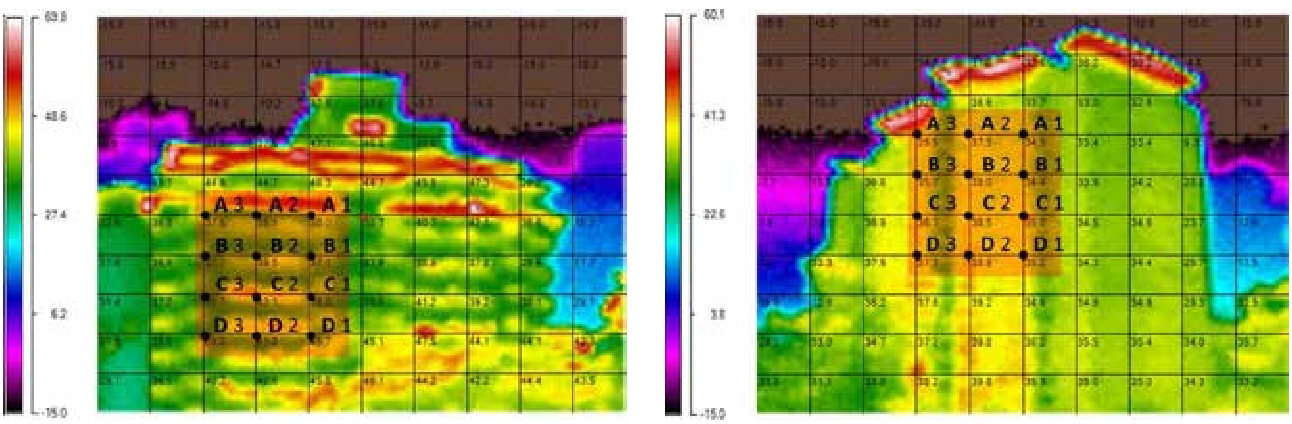


Fig. 3: Grids and selected points for the Case Study X (Right) and Case Study Y (Left). Source: Authors.

RESULTS OF THE ANALYSIS

Results of this analysis will be able to answer the fundamental issue on the level of awareness by the architects who work for Malaysian developer's company to the apartment facade designs. This survey will provide significant data and information in developing the data for the awareness model at the end of this research study. The awareness model will become a guideline in curbing global warming by reducing electricity consumption in the housing industry, especially on air conditioning due to indoor air temperature above the comfort level. The results of this survey are as illustrated in thermal surface's photo images as in Figure 4 to 9:

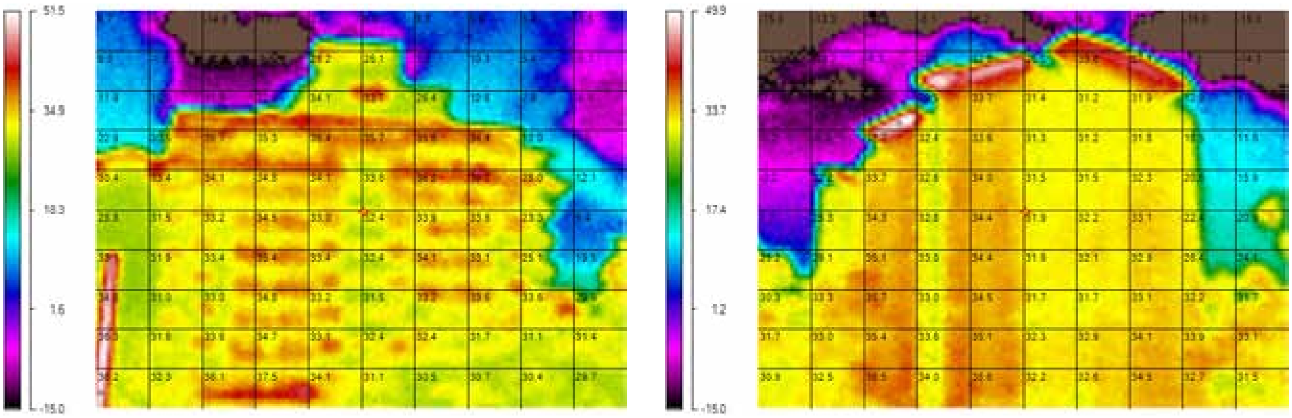


Fig. 4 : Surface temperature of the apartment facades at 1:00 pm. Source: Authors.

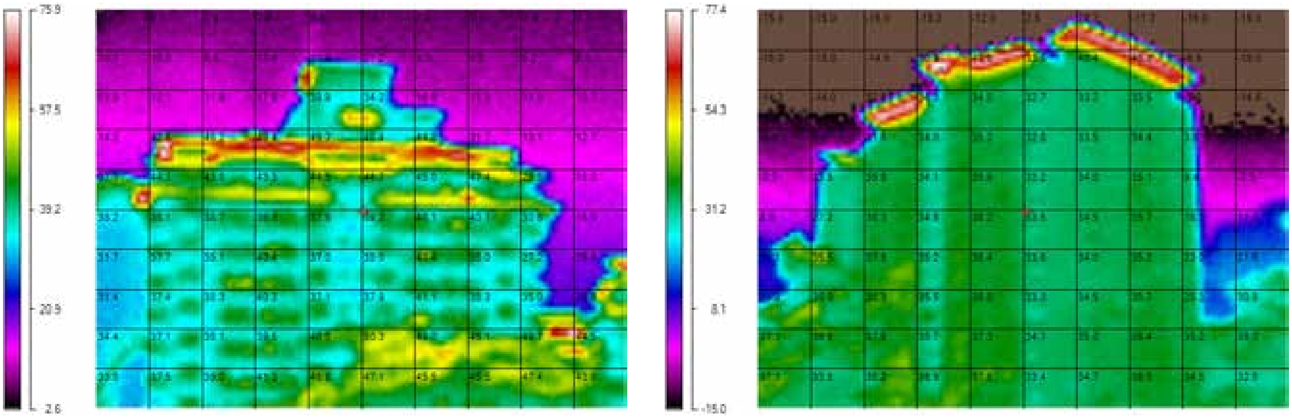


Fig. 5: Surface temperature of the apartment facades at 2:00 pm. Source: Authors.

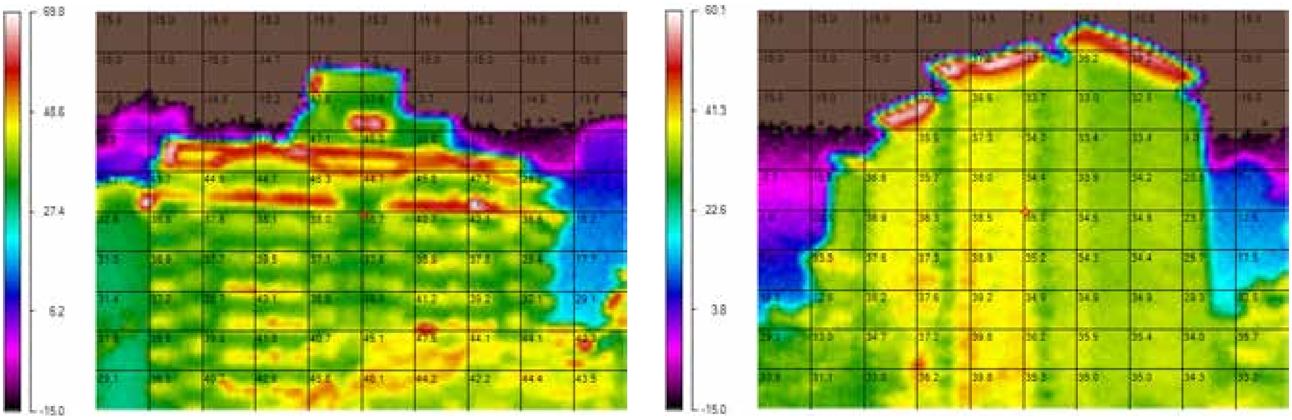


Fig. 6: Surface temperature of the apartment facades at 3:00 pm. Source: Authors.

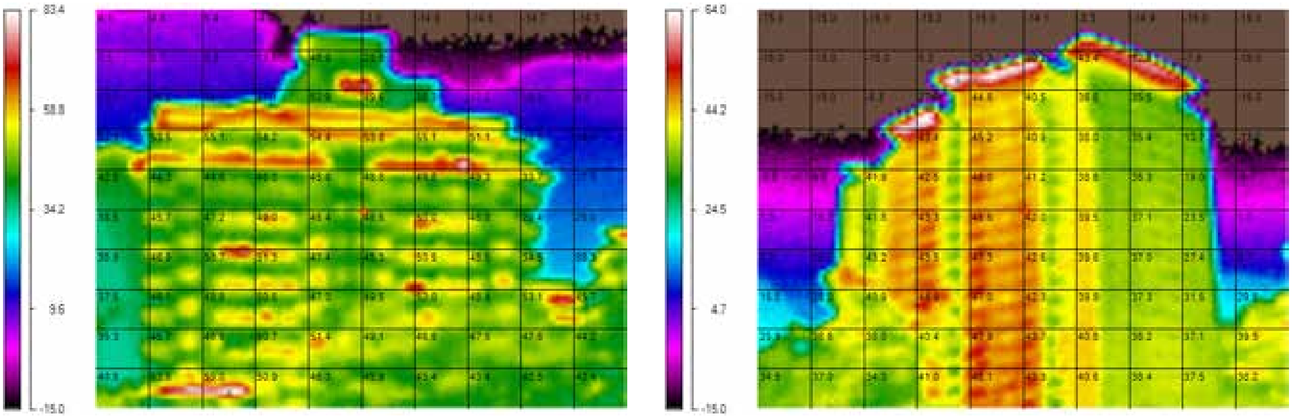


Fig. 7: Surface temperature of the apartment facades at 4:00 pm. Source: Authors.

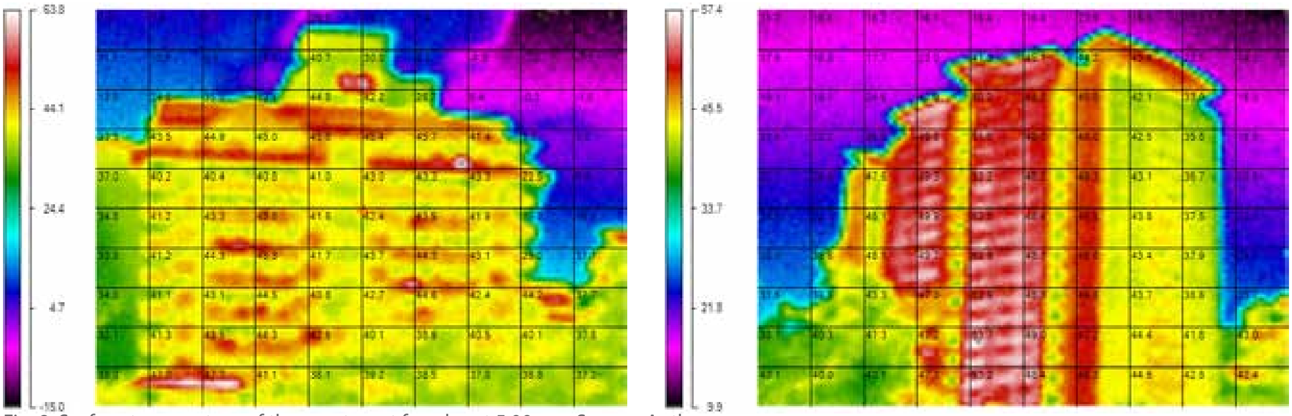


Fig. 8: Surface temperature of the apartment facades at 5:00 pm. Source: Authors.

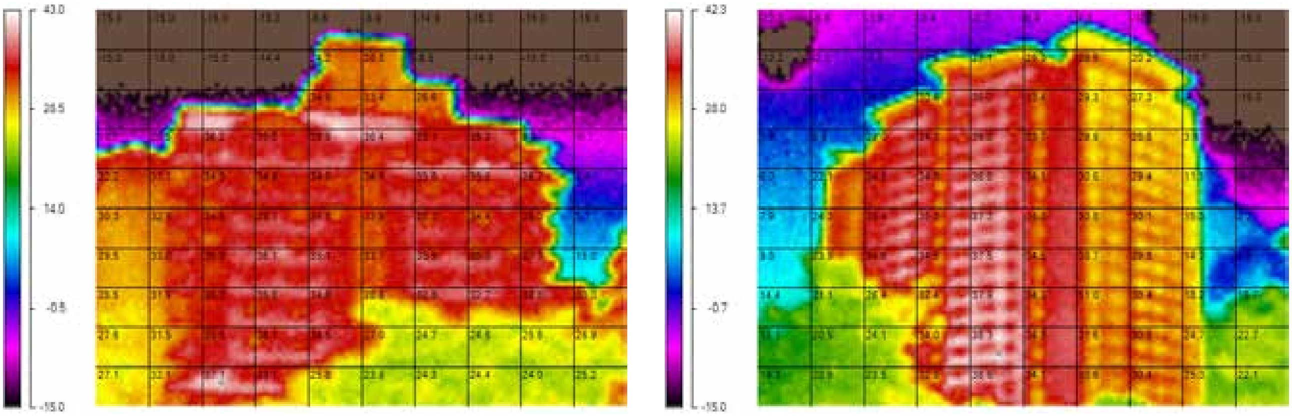


Fig. 9: Surface temperature of the apartment facades at 6:00 pm. Source: Authors.

At 3:00 pm, there was an increase of 1.91°C in the average surface temperature 1.91°C for the Case Study X from 34.60°C to 36.51°C in contrast to 1.03°C the Case Study Y from 38.57°C to 39.60°C.

At 4:00 pm, the average surface temperature of the Case Study X rose from 36.51°C to 43.71°C with an increase of 7.2°C in comparison to the Case Study Y from 39.60°C to 49.80°C with an inflation of 10.2°C.

At 5:00 pm, the Case Study X had the average surface temperature upswing from 43.71°C to 50.04°C with 6.33°C while in the Case Study Y, the temperature had a decrease from 49.80°C to 43.77°C with -6.03°C.

At 6:00 pm, the Case Study X and Y had a decrease of average surface temperature. The Case Study X had a temperature decline from 50.04°C to 35.23°C with -14.81°C in contrast to the Case Study Y from 43.77°C to 35.40°C with -8.37°C.

The highest temperature of the Case Study X was 50.04°C at 5:00 pm while the Case Study Y was 49.80°C at 4:00 pm.

Table 1: The results (temperature point A) for the Case Study X (left) and Case Study Y (right). Source: Authors.

Temperature	Case Study X in °C				Case Study Y in °C			
Time	A1	A2	A3	Average	A1	A2	A3	Average
1:00 PM	31.3	33.6	32.4	32.43	34.1	34.8	34.1	34.33
2:00 PM	32.8	35.2	34.0	34.00	37.9	39.3	38.7	38.63
3:00 PM	34	39.3	35.5	36.27	38	38.1	37.6	37.90
4:00 PM	40.9	45.2	43.4	43.17	45.9	46	44.6	45.50
5:00 PM	48	51	49.6	49.53	41	40.8	40.4	40.73
6:00 PM	33.7	36	34.3	34.67	34.6	34.9	34.5	34.67
Average of A1, A2 and A3				39.53	Average of A1, A2 and A3			40.69

Table 2: The results (temperature point B) for case study 1 (left) and case study 2 (right). Source: Authors.

Temperature	Case Study X in °C				Case Study Y in °C			
Time	B1	B2	B3	Average	B1	B2	B3	Average
1:00 PM	31.5	34	32.6	32.70	33	34.5	33.2	33.57
2:00 PM	33.2	35.9	34.1	34.40	37	40.4	39.1	38.83
3:00 PM	34.4	38	35.7	36.03	37.1	39.5	37.7	38.10
4:00 PM	41.2	46	42.5	43.23	46.4	49	47.2	47.53
5:00 PM	48.3	52.2	49.3	49.93	41.6	43.6	43.3	42.83
6:00 PM	34.1	36.8	34.8	35.23	34.5	35.1	34.5	34.70
Average of B1, B2 and B3				39.77	Average of B1, B2 and B3			41.83

Table 3: The results (temperature point C) for case study 1 (left) and case study 2 (right). Source: Authors.

Temperature	Case Study X in °C				Case Study Y in °C			
Time	C1	C2	C3	Average	C1	C2	C3	Average
1:00 PM	31.9	34.4	32.8	33.03	33.4	35.4	33.4	34.07
2:00 PM	33.5	36.2	34.6	34.77	37.1	40.3	38.3	38.57
3:00 PM	35	38.5	36.3	36.60	38	42.1	38.7	39.60
4:00 PM	42	46.6	43.3	43.97	47.4	51.3	50.7	49.80
5:00 PM	48.4	52.5	49.9	50.27	41.7	45.3	44.3	43.77
6:00 PM	34.3	37.3	35	35.53	35.1	36.1	35	35.40
Average of C1, C2 and C3				41.40	Average of C1, C2 and C3			41.43

Table 4: The results (temperature point D) for case study 1 (left) and case study 2 (right). Source: Authors.

Temperature	Case Study X in °C				Case Study Y in °C			
Time	D1	D2	D3	Average	D1	D2	D3	Average
1:00 PM	31.9	34.4	33	33.10	33.2	34.8	33	33.67
2:00 PM	33.6	36.4	35.7	35.23	40.8	39.5	38.1	39.47
3:00 PM	35.2	38.9	37.3	37.13	40.7	41.8	39.3	40.60
4:00 PM	42.6	47.3	43.5	44.47	47	50.8	48.8	48.87
5:00 PM	48.7	52.9	49.7	50.43	40.8	44.5	43.1	42.80
6:00 PM	34.5	37.5	34.5	35.50	34.8	35.8	35.2	35.27
Average of D1, D2 and D3				40.55	Average of D1, D2 and D3			41.40

DISCUSSION

The analysis as in Table 5 and Figure 11 provides the following findings:

Both of the case studies had recorded average surface temperatures with a steady increase starting with 32.82°C with an average increase of temperature ranging from 1.78°C to 10.2°C. It is the normal temperature pattern in a tropic.

In general, the results show that all selected points in the Case Study Y have higher average surface temperature than the Case Study X except at 5:00 pm.

The highest surface temperature of the Case Study X was 50.04°C at 5:00 pm while the Case Study Y was 49.80°C at 4:00 pm.

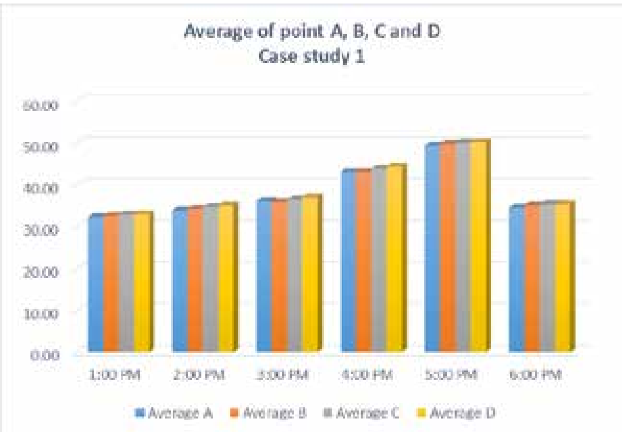
After 5:00 pm, the average surface temperature of the Case Study X had dropped compared to the Case Study Y at 4:00 pm due to the sunset about 7:00 pm

The time from 4:00 to 5:00 pm has the most heat gain problem due to high surface temperatures.

All the average surface temperatures recorded in both of the case studies are higher than the average highest temperature recorded in Putrajaya which is 32.4°C. This means the case studies do not achieve to have their west facade design with lower than outdoor air temperature during the evening time. The façades have a problem of heat gain factor which causes solar radiation to the apartments' indoor area.

Table 5. The average results of the selected points (points: A, B, C and D) for both case studies. Source: Authors.

Temperature	Case Study X in °C					Case Study Y in °C				
Time	A	B	C	D	Average	A	B	C	D	Average
1:00 PM	32.43	32.70	33.03	33.10	32.82	34.33	33.57	34.07	33	34.07
2:00 PM	34.00	34.40	34.77	35.23	34.60	38.63	38.83	38.57	38.1	38.57
3:00 PM	36.27	36.03	36.60	37.13	36.51	37.90	38.10	39.60	39.3	39.60
4:00 PM	43.17	43.23	43.97	44.47	43.71	45.50	47.53	49.80	48.8	49.80
5:00 PM	49.53	49.93	50.27	50.43	50.04	40.73	42.83	43.77	43.1	43.77
6:00 PM	34.67	35.23	35.53	35.50	35.23	34.67	34.70	35.40	35.2	35.40



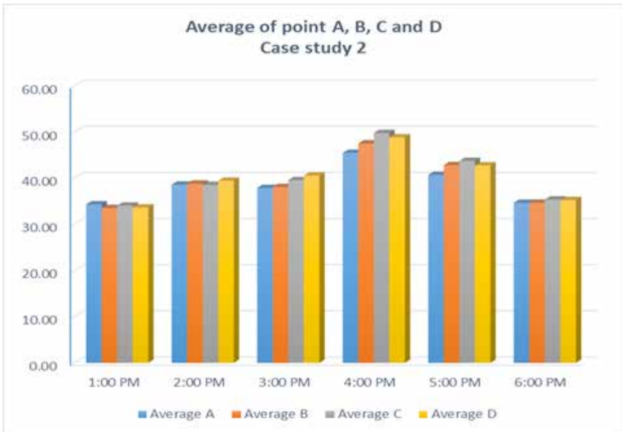


Fig. 10: The average surface temperatures of the Case Study X (Left) and Y (Right). Source: Authors.

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HOW TO CITE THIS ARTICLE
Hassan, A.S. & Arab, Y. (2019). SFundamental Study on Thermal Surface Analysis of Late Modern Styles' Apartments with Case Studies in Malaysia. *Journal of MANZAR*, 10 (44): 18-25.

DOI: 10.22034/manzar.2018.80492
URL: http://www.manzar-sj.com/article_80492_en.html