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Evaluation of Architectural Design Features of Melaka Traditional Malay House with Open Interior Space Affecting Its Thermal Performance

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Abstract: Rapid development has brought about various innovations in the construction technology for modern residential areas. However, the development has resulted in the creation of an urban heat island that has led to discomfort in living conditions. Modern architecture has replaced the design principles of traditional Malay houses (TMH). Some studies have demonstrated that modern architecture designs often lack the passive thermal advantages inherent in traditional architecture. Accordingly, this study evaluated the design features that affected the interior thermal performance of Melaka TMH by quantifying the heat transfer coefficient (HTC) and comparing it with the physical inventory data. Fieldwork was conducted in two stages: (1) pre-measurement (physical inventory) and (2) non-invasive measurement (thermal data). Findings revealed that *rumah tengah* (middle house) recorded the highest HTC value at 14,362,526.42 W, whereas *anjung* (porch) displayed the lowest HTC value at 600.08 W; both utilising zinc roofing with a U-value of 164,286 W/m²°C. Key determinants of HTC were identified as the material properties and surface area, while factors such as floor area and elevation from ground level had no significant impact on HTC or interior thermal conditions. Additionally, surface area and materials used in openings facilitated the inward and outward transfer of heat, with roof height affecting warm air circulation within a space. These findings can contribute to scientific discussions on sustainable design practices and technological applications in modern residential architecture.

Keywords: Heat transfer coefficient, Interior thermal performance, Malay house, Sustainable, Traditional architecture

INTRODUCTION

Malaysia is one of the most urbanised nations in East Asia and among the world's fastest-urbanising regions (IRENA [International Renewable Energy Agency], 2023; O'Neill, 2024). The urbanisation rate in Malaysia increased thrice over the last 50 years, from 28.4% in 1970 to 75.1% in 2020 (Department of Statistics Malaysia, 2011; Trisha, 2022). Regrettably, the concept of development has resulted in the emergence of the urban heat

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island (UHI) phenomenon (Manurung, Sastrosasmito and Pramitasari, 2022; Misni, Jamaluddin and Kamaruddin, 2015; Brahimi, Benabbas and Djaghrouri, 2023). The phenomenon has led to discomfort in the living environment due to the increase in air temperature (Misni, Jamaluddin and Kamaruddin, 2015; Buyadi, Mohd and Misni, 2014; Misni et al., 2020; Sakka et al., 2012; Brahimi et al., 2023).

Currently, contemporary architecture has diverged significantly from traditional architecture's basic design (Husen and Mohamed, 2021), which is equal to substituting traditional values (CIDB [Construction Industry Development Board] Malaysia, 2023). Some research studies found that modern architecture does not have as good passive thermal building designs as traditional architecture and that it also has impaired interior thermal performance (ITP) (Al Horr et al., 2016; Lotfabadi, 2019; Ozcelik, Becerik-Gerber and Chugh, 2019; Rosone, 2020). To address thermal challenges and to regulate ideal interior thermal performance, occupants in modern houses increasingly rely on artificial ventilation systems, such as air-conditioners. This dependency results in significant energy inefficiencies (Hassan and Ramli, 2010). Moreover, the demand for air-conditioners is increasing due to the rising outdoor temperatures (*The ASEAN Post*, 2020). As a result, studies have begun to acknowledge the superiority of sustainable architecture, where buildings implement passive design strategies that are responsive to the relevant climatic conditions, specifically the ITP for occupant comfort. Traditional architecture, for instance, in traditional Malay houses (TMH) in Malaysia has practiced this design approach (Luo, 2020; Hyde, 2008; Olgyay and Olgyay, 2015; Oliver and Aalen, 1997; Sassi, 2006; Zhai and Previtali, 2010).

The thermal performance of a building refers to the process of modelling energy transfers between the building and its surroundings (Joseph, Jose and Habeeb, 2015; Misni, 2015; Nordin and Misni, 2017; Brahimi, Benabbas and Djaghrouri, 2023). In Malaysia, few studies have evaluated the ITP of TMH. Nonetheless, most experimental studies have been keen on the basic design of *bumbung panjang* (long roof) and *bumbung limas* (hipped roof) of Malay houses without an open passageway or *pelantar* (deck) (e.g., Hassan and Ramli, 2010; Johari and Said, 2021; Saad et al., 2019; Toe and Kubota, 2013). Moreover, the houses' design and layout commonly include *serambi* (verandah/front hall), *rumah ibu* (main house) and *rumah dapur* (kitchen). Hence, there is a deficiency of ITP assessment on TMH with *pelantar*, such as Melaka houses. Melaka houses, the only TMH with *pelantar*, offer natural ventilation and lighting to the interior space (Hassin and Misni 2022; Yaaman and Ramli, 2013), commonly known as the intermediate open space/courtyard.

Therefore, this study aimed to evaluate the design features that affected the interior thermal performance of TMH in Melaka by quantifying its heat transfer coefficient. The Sustainable Development Goal (SDG) criteria, specifically SDG 7 (Affordable and clean energy), SDG 9 (Industry, innovation and infrastructure) and SDG 13 (Climate action), are all relevant to this study. The findings will contribute to scientific discussions on sustainable practices in modern residential design and the technology used. This study aspires to provide useful insight regarding the effectiveness of practices in the climatic design strategies of TMH.

LITERATURE REVIEW

Previous studies have emphasised that every detail in the construction of TMH aims to create a reasonable ITP. Besides, this remarkable architecture underscores the importance of a climatic design strategy, ensuring optimal thermal conditions for the residents. Linear posts and lintels raised on stilts, minimal partitions, operable windows, a ventilation lattice and high or steeply sloping roofs with gables at both ends are some of the most important features of TMH (Ju, Omar and Ko, 2012; Sahabuddin, 2012; Teh and Nasir, 2014). Each of these features contributes to the thermal qualities of this vernacular architecture.

The climatic design of TMH consists of two main factors: building disposition and physical architectural aspects. Building disposition is classified into two categories: building orientation and outdoor environment. The appropriate building orientation can reduce the heat gain by allowing the wind to ventilate the house (Misni, Baird and Allan, 2013). Meanwhile, Brahimi et al. (2023) arrange the houses randomly with appropriate natural vegetation to provide shade and a cooler microclimate. Besides that, the physical aspects of architecture encompass the building envelope and the design or form of the houses themselves. These include walls with openings and minimal interior walls to allow cross-air ventilation. Raised floor can catch winds of a higher velocity. Besides, the roof space facilitates air ventilation through the attic space, thereby effectively cooling the house. The broad roof eaves allow for the control of direct solar radiation. The practice of these strategies aims to enhance ITP. In addition, according to Kubota and Toe (2012), one factor that can enhance the thermal performance of TMH is the material selection.

The thermal performance of a building refers to the process of modelling various heat exchanges (heat gains or losses) between it and its surroundings (Zhai and Previtali, 2010; Nordin and Misni, 2017). It generally refers to how well something holds or resists heat transfer. It depends on four main factors (as shown in Table 1): (1) design variables, (2) material properties, (3) weather data or environmental factors and (4) a building's usage data (Ford, Schiano-Phan and Vallejo, 2020; Machdijar, Setyowati and Purnomo, 2019; Nayak and Prajapati, 2006). The ITP of a building can be measured through an analysis of the total heat transfer coefficient (HTC) using Equation 1, whereas Equation 2 calculates the heat transfer for each house's elements (floor, wall and roof).

$$Q_{total} = \Sigma(U_i \times A_i \times \Delta T) \quad \text{Eq. 1}$$

$$Q = \Sigma(U_i \times A_i \times \Delta T) \quad \text{Eq. 2}$$

where, Q = Heat gain and heat loss/rate of heat transfer (W); U = Overall heat transfer coefficient ($W/m^2.°C$), which is the reciprocal of the thermal resistance of the wall or other building components; A = Surface area of the building components (e.g., walls and roofs) through which heat is being transferred (m^2); ΔT = Temperature difference between the indoor and outdoor (°C) and i = building element (e.g., walls, floors, roofs and windows).

Thermal performance measures temperature variations within a non-conditioned building over a particular time and influences the estimation of the duration of uncomfortable periods (Nayak and Prajapati, 2006). These quantifications enabled one to evaluate a building's suitability and contribute to the improvement of designs for energy-efficient buildings that provide comfortable indoor conditions. Good indoor thermal conditions create a comfortable (without heat stress or thermal strain) and healthy environment for occupants, thereby sustaining their living quality. Traditional residential buildings have long acknowledged the importance of maintaining a comfortable indoor thermal condition in their structures (Song, Lin and Zhu, 2002).

METHODOLOGY

A non-invasive measurement technique was employed through fieldwork to evaluate the design features of a Melaka house and their impact on the ITP. This research applied a two-stage process of data collection and analysis, as shown in Figure 1.

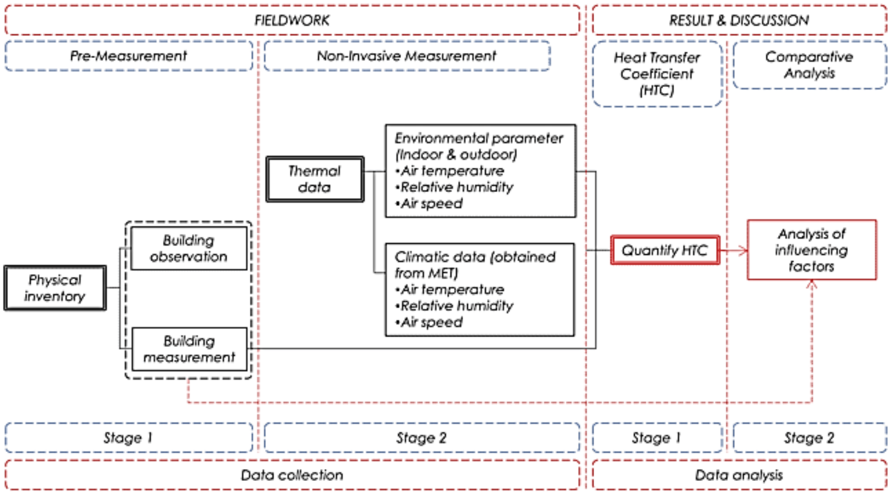

Figure 1. Data collection methods and analysis framework

Pre-measurement

A physical inventory measurement was utilised to collect physical data of the case study in Stage 1 of the fieldwork. This data collection consisted of two methods: physical observation and measurement. The following information on data-gathering methods for the physical inventory is listed in Table 1. All the data were recorded into an inventory table, photographic images and schematic drawings.

Table 1. Variables of the physical inventory process

Items	Variables	Tools and Equipment
Building observation	1. House form and typology 2. Spatial division 3. Ventilation devices 4. Shading devices 5. The material used (floor, wall, ceiling/roof) 6. Ground cover and vegetation (yard) 7. Building and opening orientation	1. Digital cameras 2. Physical inventory forms 3. Schematic sketches
Physical measurement	1. Size of the yard 2. Size of the wall and opening 3. Surface area of floor, wall and roof 4. Roof/ceiling height 5. Floor/height from ground level 6. Type of material and the thickness	1. Measuring tape/ digital rangefinder 2. Physical inventory forms 3. Schematic sketches

Non-invasive Measurement

Thermal data measurements were conducted in both the interior and exterior areas of the houses. The study used a Delta OHM HD32.3 data logger to record air temperature, relative humidity data and air speeds. Generally, indoor data acquisition points should be measured at least half a metre from any wall and 1.1 m above floor level (ASHRAE [American Society of Heating, Refrigerating and Air-Conditioning Engineers], 2017; Kakoulli, Kyriacou and Michaelides, 2022). For outdoor data, the instruments were set to record indirect solar radiation or in the shade, as direct sunlight records the sun's heat rather than the ambient air's heat, potentially leading to inaccurate readings (Rice, 2018). Meanwhile, the data acquisition point for outdoors was at least 5 m from the house's walls and 1.5 m above the ground (Collow, 2020). This is because the wind speed and direction may be dramatically affected by all physical obstructions near the ground level (Misni, Baird and Allan, 2013; Hassin et al., 2023; Prodata Weather Systems, 2022). The data were recorded within 12 hours, at 30-minute intervals, from 7:00 a.m. to 7:30 p.m. No measurements were taken at night, from 8:00 p.m. to 6:30 a.m. During the measurements, the houses were occupied and the windows were kept open at all times. The data were only taken under the overcast sky (partly cloudy), a typical sky condition in Malaysia.

Data Analysis

In Stage 1 of data analysis, the HTC value was quantified using Equations 1 and 2. These results were then used in Stage 2 of data analysis to examine house features affecting ITP. By comparing data from Stage 1 of fieldwork with HTC values, the analysis provided insights into how specific house features affect the HTC and, consequently, the overall thermal performance of the interior.

DATA COLLECTION

Physical Inventory Data

A Melaka TMH located at Kampung Pondok Kempas in Selandar, Jasin, Melaka, with measurements of 2° 21' 1.53" NL 102° 22' 13.8" EL, was chosen as the case study of the current study (as shown in Figure 2[a]). Built in the 1940s, the house had a total floor area of 128.41 m^2. The house faced east-west, with the qibla pointing in the direction of 293°. The house was surrounded by an ample lawn yard, with some of its compound surfaces covered by tarmac (as shown in Figure 2[b]).

Figure 2. (a) The key plan of Selandar, Jasin, Melaka and location plan of the case study in Kampung Pondok Kempas, (b) the site plan and (c; d) the house's spatial division.

On both sides of the house, there were crop-bearing fruit trees with medium canopy sizes. The typology of TMH Melaka was a *berbandung tiga* (refers to a three-part linear spatial configuration), characterised by 12 main pillars and spatial divisions, such as *anjung*, *serambi*, *rumah ibu*, *pelantar*, *rumah tengah*, *loteng* (attic/loft) and kitchen (as shown in Figures 2[c] and 2[d]). The house experienced various modifications and extensions, including the addition of toilets and the renovation of the kitchen with concrete materials. The original bedroom was in *rumah ibu*. However, the expansion of the family led to the addition of three bedrooms in *rumah tengah*. Plywood was used as an interior partition/wall to demarcate the rooms. Table 2 shows the area and height of each spatial division in the original house (m^2).

Table 2. The area and height of the case study

Typology	*Berbandung Tiga*					
Spatial Division (Original House)	***Anjung***	***Serambi***	***Rumah Ibu***	***Pelantar***	***Rumah Tengah***	***Loteng***
Floor area (m²)	7.25	13.27	21.08	24.64	24.76	21.50
Height from ground (m)	1.0	1.13	1.38	–	1.32	Upper *rumah ibu*
Roof height (m)	3.19	2.96 to 2.17	2.80	–	5.49	2.53

The case study featured a *bumbung panjang* (long roof) house, as illustrated in Figure 3(a). The house was designed with a double-slope roof, indicating ample roof space. The roof had gable end features with ventilation panels (as shown in Figure 3[b]). The material profile used for the building envelopes of each space is specified in Tables 3(a) to 3(c). Meanwhile, Table 4 lists the ventilation devices used in the house.

(a)

(b)

Figure 3. (a) The front elevation of the house facing west direction, with the main entrance oriented towards the south and (b) the second entrance at *pelantar* design with open roofing.

Table 3(a). The material used on the building envelope (roof) for each spatial division

Spatial Division	Building Envelope: Roof		
	Material	**Surface Area (m²)**	**Thickness (m)**
Anjung	Unglazed terracotta tiles	11.54	0.0250
Serambi	Unglazed terracotta tiles	27.07	0.0250
Rumah ibu	Unglazed terracotta tiles	39.91	0.0250
	Timber plank ceiling	29.40	0.0400

(*Continued on next page*)

Table 3(a). *Continued*

Spatial Division	Building Envelope: Roof		
	Material	Surface Area (m^2)	Thickness (m)
Pelantar	Unglazed terracotta tiles (overhang from RI)	8.05	0.0250
	Zinc sheet (overhang from RT)	6.55	0.0007
Rumah tengah	Zinc sheet	51.46	0.0007
Loteng	Unglazed terracotta tiles	39.91	0.0250

Table 3(b). The material used on the building envelope (wall) for each spatial division

Spatial Division	Building Envelope: Wall		
	Material	Surface Area (m^2)	Thickness (m)
Anjung	Ventilated timber *pagar musang* (a type of decorative railing)	5.94	0.020
	Ventilated timber panel	4.95	0.030
Serambi	Ventilated timber panel	22.60	0.030
	Timber plank	18.36	0.030
Rumah ibu	Timber plank	59.10	0.030
Pelantar	Soft burnt clay bricks	18.47	0.100
	Timber plank (adjacent wall)	32.29	0.030
	Plywood panel (adjacent wall)	13.80	0.012
	Concrete block (kitchen wall)	18.67	0.102
Rumah tengah	Timber plank	44.00	0.030
	Plywood panel	13.80	0.012
Loteng	–	–	–

Table 3(c). The material used on the building envelope (floor) for each spatial division

Spatial Division	Building Envelope: Floor		
	Material	Surface Area (m^2)	Thickness (m)
Anjung	Timber plank	7.25	0.04
Serambi	Timber plank	13.27	0.04
Rumah ibu	Timber plank	21.08	0.04

(*Continued on next page*)

Table 3(c). *Continued*

Spatial Division	Building Envelope: Floor		
	Material	Surface Area (m^2)	Thickness (m)
Pelantar	Cemented concrete	24.64	0.62
Rumah tengah	Timber plank	24.76	0.04
Loteng	Timber plank	21.50	0.04

Table 4. Ventilation devices used in the house

Spatial Division	Ventilation Devices		
	Passive		Mechanical
Anjung	1. Ventilated *pagar musang* 2. Floor joist 3. Roof joist		×
Serambi	1. Ventilated *pagar musang* 2. Ventilated wall panel 3. Full height operable window with louvers 4. Roof joist 5. Floor joist		×
Rumah ibu	1. Half-height operable windows 2. Roof joist 3. Floor joist 4. Ventilated gable end		Standing fan
Pelantar	1. Open roofing 2. Ventilated wall		×

(*Continued on next page*)

Table 4. *Continued*

Spatial Division	Ventilation Devices		
	Passive		Mechanical
Rumah tengah	1. Full-height operable windows 2. Ventilated *pagar musang* 3. Roof joist 4. Floor joist 5. Ventilated gable end		Standing fan
Loteng	1. Ventilated gable end 2. Roof joist 3. Floor joist		×

Thermal Data

Thermal measurements were conducted between 24th and 26th September 2022. The original building's spatial divisions (i.e., *anjung*, *serambi*, *rumah ibu*, *pelantar*, *rumah tengah* and *loteng*) were categorised according to the interior hourly thermal data, as illustrated in Figures 4(a) and 4(b). Meanwhile, Table 5 presents the average and comparison of the interior air temperature, air speed and exterior thermal data over a 12-hours period. The hourly climate data were obtained from Felda Kemendor Station, Melaka, Malaysia.

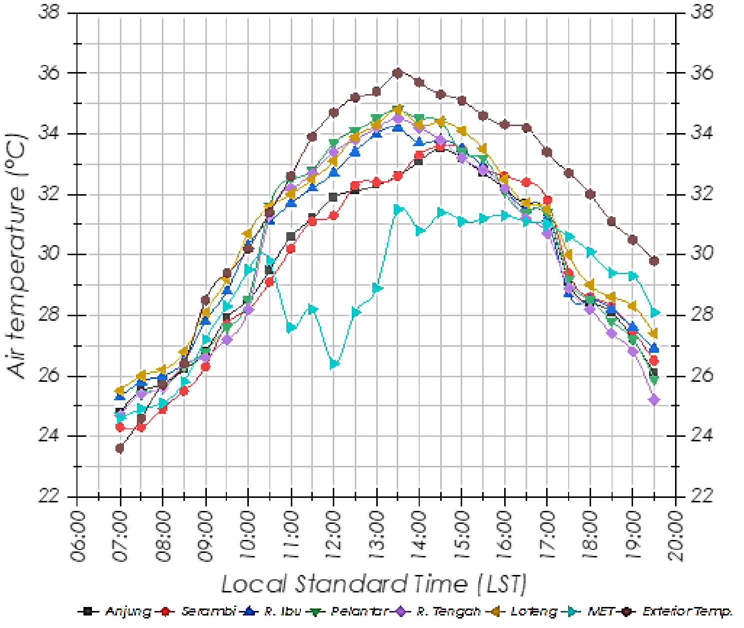

Figure 4(a). Average hourly air temperature at the interior and exterior thermal data of the case study

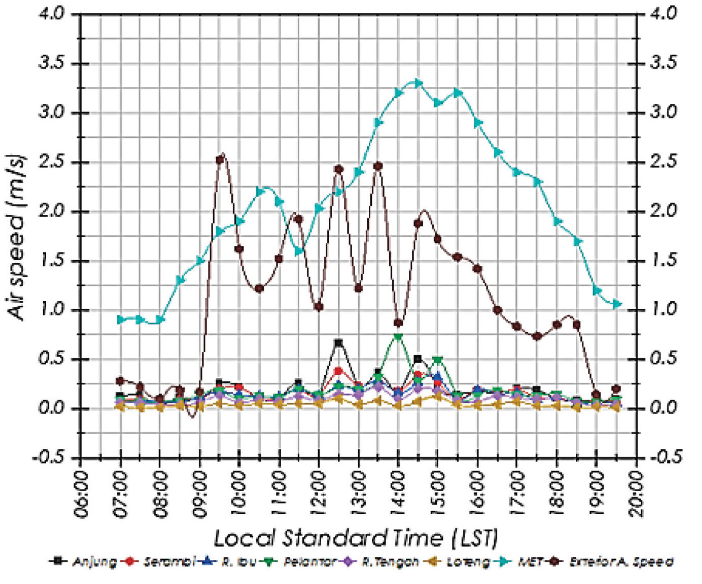

Figure 4(b). Average hourly air speed at the interior and exterior thermal data of the case study

Table 5. Ventilation devices used in the house

Spatial Division		**Air Temperature (°C)**	**Air Speed (m/s)**	**Relative Humidity (%)**
Interior	*Anjung*	29.7	0.19	76.6
	Serambi	29.6	0.16	76.4
	Rumah ibu	30.3	0.14	74.1
	Pelantar	30.3	0.18	75.6
	Rumah tengah	30.0	0.10	74.4
	Loteng	30.7	0.04	71.6
Exterior		31.7	1.11	61.2

Based on Figure 4(a), the air temperature uniformly ascended from early morning until late noon. After 15 hours, the recorded data continued to decline. Most of the time, the air temperature ranged between 31°C and 33°C. Meanwhile, the recorded air speed data in Figure 4(b) remained relatively consistent throughout the day, ranging between 0.08 m/s and 0.15 m/s. As for the average thermal data, air temperature ranged between 29.6°C and 30.7°C, air speed between 0.04 m/s and 0.19 m/s and relative humidity was between 71.6% and 76.6%. Furthermore, in average thermal data according to each spatial division, *serambi* recorded the lowest temperatures than the other spatial divisions, with only 1°C less than the temperature in *anjung*. The mean differences between spatial divisions were 0.6°C. The highest temperature among the spatial divisions was *loteng* (30.7°C); nonetheless, the air speed rate was the lowest among the spatial divisions at 0.04 m/s. Meanwhile, *rumah ibu* and *pelantar* registered similar temperatures at 30.3°C, differing only by 0.3°C from *rumah tengah*'s temperature. However, air speed rates varied, with a difference of 0.08 m/s between them. The highest air speed rate among the spatial divisions was in *anjung*, with 0.19 m/s. To compare with the interior and exterior thermal data, the mean differences were 1.6°C air temperature and 0.97 m/s air speed, while the overall humidity was lower with a difference of around 0.8% to 15.4%.

RESULTS AND DISCUSSION

Design Features Affect the Interior Thermal Performance Based on Heat Transfer Coefficient Value

Table 6 quantifies and represents the HTC values of each spatial division using Equations 1 and 2.

Table 6. The total value of HTC in each of the spatial divisions

Spatial Division and Floor Area (m^2)	Air Temperature (°C)	Building Envelope	Material	Surface Area (m^2)	U-Value	HTC (W)
Anjung (7.25)	29.7	Roof	Unglazed terracotta tiles	11.54	26.00	600.08
		Wall	Ventilated timber *pagar musang*	5.94	6.00	71.28
			Ventilated timber panel	4.95	4.67	46.23
		Opening	Timber opening	9.60	2.80	53.76
		Total	771.35			
Serambi (3.27)	29.6	Roof	Unglazed terracotta tiles	27.07	26.00	1,478.02
		Wall	Ventilated timber panel	22.60	4.67	221.79
			Timber plank	18.36	4.67	111.41
		Opening	Timber panel door	2.30	4.67	22.57
			Timber panel window	4.50	7.00	66.15
		Total	1,899.94			
Rumah ibu (21.08)	30.3	Roof	Unglazed terracotta tiles	39.91	26.00	1,452.20
			Timber plank ceiling	29.40	3.50	144.06
		Wall	Timber plank	59.10	4.67	385.11
		Opening	Timber panel window	1.00	7.00	9.80
			Timber panel door	2.20	4.67	14.38
		Total	2,005.55			

(*Continued on next page*)

Table 6. *Continued*

Spatial Division and Floor Area (m²)	Air Temperature (°C)	Building Envelope	Material	Surface Area (m²)	U-Value	HTC (W)
Pelantar (24.64)	30.3	Roof	Unglazed terracotta tiles	8.05	26.00	293.02
			Zinc sheet	6.55	164,286.00	1,506,503.00
		Wall	Soft burnt clay bricks	18.47	8.00	206.83
			Timber plank	13.83	4.67	90.44
		Opening	Timber panel door	2.80	4.67	18.31
			Ceramic *lubang angin* (ventilation hole)	0.09	75.00	9.45
			Clay *lubang angin*	0.30	14.00	5.88
		Total	1,507,127.74			
Rumah tengah (24.76)	30.0	Roof	Zinc sheet	51.46	164,286.00	14,361,873.85
		Wall	Timber plank	44.00	4.67	349.31
			Plywood panel	13.80	10.00	234.6
		Opening	Timber panel window	2.20	7.00	26.18
			Plywood door	2.20	10.00	37.4
			Ventilated timber (gable end)	0.64	4.67	5.08
		Total	14,362,526.42			
Loteng (21.50)	30.7	Roof	Unglazed terracotta tiles	39.91	26.00	1,037.66
		Wall	–	–	–	–
		Opening	Ventilated timber (gable end)	0.64	4.67	5.08
		Total				1,042.74

Table 6 reveals that floor area (m^2) and height of the space from the ground (m) did not impact the HTC or the interior thermal data of the case study. The HTC value's main factors were the material used and its building envelope surface area (m^2). In this case study, the building elements that highly influenced HTC value were roofs and walls. For example, *rumah tengah* and *pelantar* both recorded higher values of HTC than other spatial divisions. Even though *pelantar* recorded a slightly higher interior temperature than *rumah tengah*, the HTC value showed a distinct difference, measuring 12,855,398.68 W. The main factor contributing to this HTC was that both spatial had similar use of the roofing material, namely zinc sheet, with a value of U 164,286 W/m²°C, indicating a high thermal conductivity. However, the significant difference in the HTC value of 12,855,398.68 W was attributed to the significant contrast in the surface area of the zinc sheet roofing, with *rumah tengah* measuring 51.46 m^2 and contributing 14,361,873.85 W and *pelantar* measuring 6.55 m^2 and contributing 1,506,503 W. Moreover, the unglazed terracotta tiles used in other spatial divisions also recorded an HTC value of over 1,000 W.

Furthermore, the wall material, timber in this case study, generally had a low U-value, ranging below 10 W/m²°C. Nonetheless, surface area (m^2) significantly affected the HTC value. For example, all spatial divisions used timber planks with a U-value of 4.67 W/m²°C as the wall material. However, *rumah tengah* had the highest HTC value among them all. This was due to the wider surface area of the timber plank, measuring 44 m^2, compared to other spatial dimensions, which contributed approximately 349.31 W to the HTC value. Though *rumah tengah* recorded a significantly higher HTC value than *pelantar*, the interior temperature showed a contrary trend. The absence of a wall or partition between *rumah tengah* and *pelantar* explained this. The HTC value of opening materials showed that the features encouraged heat to transmit freely in and out of the space without any solid obstacles. *Pelantar*, with its surface area of 3.19 m^2 and an HTC value of 33.64 W, was not as large as *rumah tengah*. However, the air speed rate, at 0.18 m/s, was the second highest among spatial divisions due to open roofing, similar to a courtyard.

Despite the use of the same material for the roof and wall, the HTC value in *anjung* (771.35 W) was significantly lower than in *serambi* (1,899.94 W). Moreover, it was the lowest value among all the spatial divisions. The reason was that the surface area of the unglazed terracotta roof tiles and timber panel or plank for the wall was wider than *anjung*, 27.07 m^2 and 40.98 m^2, respectively, contributing to 1,478.02 W and 333.2 W of HTC value, respectively. *Anjung*, an enclosed space with a ventilated timber *pagar musang* (essentially a verandah) and a large opening, had the HTC value of 88.72 W and an air speed rate of 0.19 m/s, indicating that these features encouraged heat to transmit freely in and out of the space without any solid obstacles. *Serambi*'s opening recorded a higher HTC 88.72 W compared to *anjung*'s opening 53.76 W, even though its compact surface. Thus, the thickness of a material influenced the U-value of a material and increased HTC values. The surface area of the opening demonstrates its ability to slow down the air speed, as evidenced by the 0.03 m/s decrease in air speed recorded by *serambi* over *anjung*. Additionally, based on the HTC value of the opening, it was possible to regulate the transmission of heat into and out of the space.

Rumah ibu had a slightly higher HTC value and interior temperature than *serambi*, with 105.61 W and 0.7°C differences, respectively. Despite a significant difference in the HTC value, the recorded interior temperature data from *rumah ibu* and *pelantar* were identical. The material used in a building element that highly affected HTC's value was the roof. The house had two layers of roof: unglazed terracotta tiles (1,452.2 W) and timber plank ceiling (144.06 W). The wide surface area of the timber plank (59.10 m^2) also contributed to a high HTC value (385.11 W). Despite being built with a fully enclosed wall of timber plank, *loteng* maintained a similar temperature to *pelantar*. This was due to the timber plank ceiling, which served as the floor of *loteng*. This resulted in *rumah ibu* having the lowest roof height, at 2.80 m, and a lack of openings, resulting in limited heat transmission of 24.18 W, causing warm air to circulate throughout the space. *Loteng*, with its lowest roof height of 2.53 m, also experienced this situation. The only opening it had to transmit warm air through was the ventilated gable end, with a surface area of 0.64 m^2, resulting in 5.08 W of the HTC value.

CONCLUSION

Through the quantification of the HTC value, the design features that influenced the interior thermal performance of a TMH Melaka, located at Pondok Kempas, Jasin, Melaka, Malaysia, were evaluated. The study found that floor area (m^2) and height of the space from the ground (m) did not impact the HTC or the interior thermal data of the case study. The main factors affecting the HTC value were the materials and their surface area (m^2). The building elements that highly affected HTC's value were roofs and walls. Moreover, the surface area of the opening and the materials demonstrated that these features facilitated the transfer of heat both inward and outward. In addition, the spatial height of the roof (m) can significantly influence the circulation of warm air in the space.

This study enhances the understanding of sustainable design. It shows the importance of thermal passive strategies in traditional Malay homes, which can be compared and used in modern designs, contributing to current discussions on sustainable architecture and urban heat reduction. The study demonstrated that quantitative measures, such as HTC, can assess thermal performance; thereby, setting a foundation for future research across various architectural styles in tropical climates. Additionally, this study promotes environmental sustainability through traditional designs and the findings connect to SDGs, particularly clean energy and climate action.

In addition, by integrating findings from this study into modern architectural practices, designers and innovators can develop housing schemes that respect cultural heritage and enhance energy efficiency and interior thermal comfort. This approach can lead to the development of building materials that are both environmentally friendly and effective in managing heat transfer, thereby reducing reliance on mechanical cooling systems. Furthermore, the insights gained can inform policies that promote preserving traditional architectural styles while adapting them to contemporary needs. Ultimately, these efforts contribute to a more sustainable future by fostering resilience against climate change, promoting energy efficiency and enhancing the quality of life for occupants. Engaging in scientific discussions and collaborative projects among architects, engineers and policymakers will be essential to realise these goals and implement innovative solutions that align with the SDGs, especially SDG 7, 9 and 13.

The study has important practical implications for architects, urban planners and policymakers. Architects can figure out their inspiration from the house design of TMH Melaka to create energy-efficient buildings in traditional ways that rely on natural ventilation. Policymakers can promote traditional architectural styles to improve city microclimates and combat urban heat island phenomena. Additionally, this study serves as educational material for teaching sustainable architecture, linking the idea of modern practices to traditional designs. To gain insight into this field, it is recommended that the study be carried out in other types of TMH in Malaysia. Furthermore, scientific evidence obtained through computer simulation should be provided to fully understand the design features, including the building disposition factor that influences the ITP of the investigated house. The generated simulation of the house's interior and exterior spaces can be made using computer software such as computational fluid dynamics, ENVI-met and Ecotect.

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