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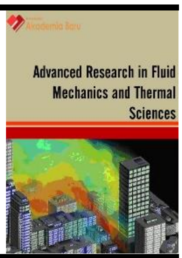

Thermal Comfort Assessment: A Comparative Study of Passive Ventilation System in Modern and Malay Traditional House

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Shahira Yacob[1], Azhaili Baharun[1,*], Julaihi Wahid[1], Siti Halipah Ibrahim[1], Viviellenie Ngitar[1], Mohd Nasrun Mohd Nawi[2], Othman Mohamed[3]

[1] Faculty of Built Environment, University Malaysia Sarawak, Malaysia
[2] School of Technology Management dan Logistic, Universiti Utara Malaysia, Sintok, Kedah, Malaysia
[3] Department of Quantity Surveying, Faculty of Built Environment, University of Malaya, 50603, Kuala Lumpur, Malaysia

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ABSTRACT

Thermal comfort is the perception in which the environment is fulfilled. Thermal comfort varies from person to person. It is necessary to make the heat generated as a result of human activities dissipate at a rate to maintain equilibrium within the body in order to maintain thermal equilibrium. Understanding thermal comfort is vital to architectural design as it serves as the basis for building design but also affects sustainable design. An experiment was conducted where thermal comfort in environmental factors were measured. Autodesk Revit and Autodesk CFD were used to analyze and simulate the air movement for both Malay traditional house and modern house. Research shows that the Malay traditional house can provide better thermal indoor comfort compared to modern house. In addition, in the same bio-climate, these buildings consume less energy than modern buildings to gain better acceptable indoor environment.

Keywords:
Thermal comfort; Malay traditional house; modern house; passive design; sustainable design

1. Introduction

Globally, people nowadays are more spending time indoor [1]. Spending more time indoor usually causing health problem which lead to sick building syndrome (SBS) and other related illness where actual reasons of the health problem cannot be identified. As stated that thermal comfort is defined as "that condition of mind, which expresses satisfaction with the thermal environment" [2]. One of the most vital parameters to consider when designing buildings is the creation of a thermally comfortable environment [3]. [4] added it should be done at the design stage itself to generate a thermally comfortable housing environment. Traditional houses built in hot humid areas generally promote natural ventilation to provide maximum thermal comfort while reducing humidity. As stated

* *Corresponding author.*
E-mail address: bazhaili@unimas.my

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by [5], traditional dwelling was built above ground to let the wind enter and leave indoor easily for ventilation. This significantly decreases the temperature of indoor air in dwellings where the occupants thermal comfort is the key design strategy.

2. Literature Review

2.1 ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers defined thermal comfort as govern of mind that shows fulfilment through the thermal nature of surrounding. The conditions for thermal comfort of occupants are affected by various factors such as environmental factors that is air temperature and air speed, radiant temperature, humidity and personal factors that is thermal insulation of clothing and metabolic rate. [6]. ASHRAE [7] describes that by closing and opening windows can achieve thermal comfort over a wider band of environmental conditions by the occupants themselves where rather than simply being passive recipients of thermal environment, occupant has an active role in achieving thermal comfort.

2.2 Traditional Houses

As stated by [8], it has been demonstrated that most traditional buildings using passive cooling systems can improve indoor thermal comfort compared to modern buildings. In the older architecture, courtyards were also used to create an appropriate thermal condition in residential buildings as an effective strategy.

2.3 Malay Traditional House

Commonly the layouts are divided by a main house, kitchen and several spaces that has transitional space such as windows and doorway for ventilation purposes especially during daytime. Usually Malay house are building with full height windows with upper ventilation openings, large thatched roof that give cooling effect indoor compared than zinc and built with wall and slab made of woods or bamboo which the slab is raised from ground to allow air movement as shown in Figure 1 and Figure 2. The house comprises of raised slab from ground level and full height of window to allow more air movement entering the house.

Fig. 1. Traditional Malay house

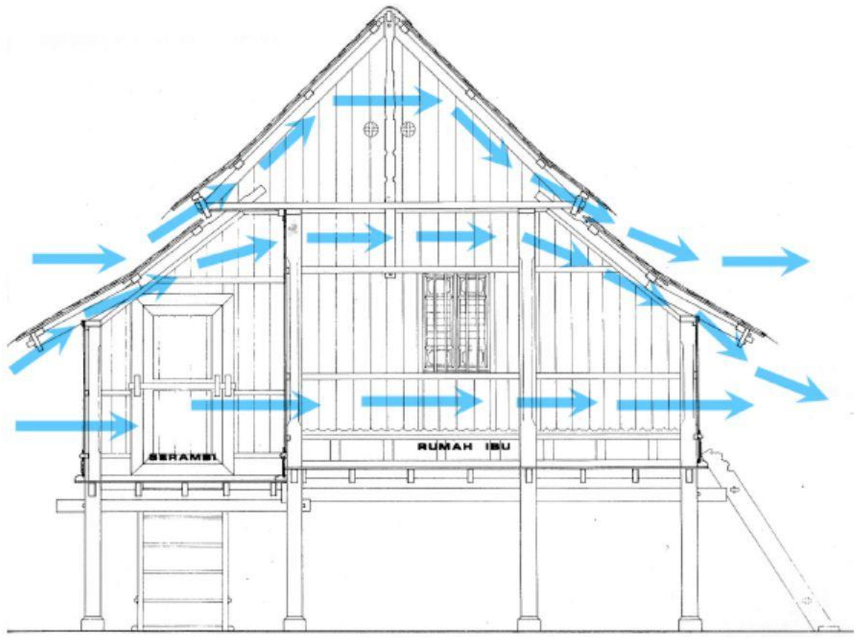

Fig. 2. Cross ventilation promotion in malay traditional house

2.4 Environmental Factors

2.4.1 Temperature

Malaysia encounter with humid climate and warm condition because Malaysia is located near to the equator. The most vital impact in Malaysia structures are high daily air temperature and high intensity of solar radiation. The air temperature generally intensifies from floor to ceiling in an enclosed space. If the difference is large enough, uneasiness may result from excessively warm temperature at the head whilst excessively cold at the feet, even though the whole body is thermally neutral. The floor temperature should range between 18°C to 29°C to minimize the discomfort. [9].

2.4.2 Humidity

Indoor air humidity, in terms of perceived dryness and possibility associated health effects is a crucial parameter (relative humidity (RH) or absolute humidity (AH)) both in the office environment and aircraft surrounding [10]. Relative humidity is the percentage of water vapor in the room air relative to the total quantity of vapor in the same room air may hold at given temperature while absolute humidity at defined pressure is the amount of water in grams per kilogram of air.

Relative humidity (RH) is the ratio of the air-vapor mixture's actual vapor pressure to the saturated water vapor pressure at the same dry-bulb time of 100. Condensation on cold surfaces and the delay of human heat loss through evaporative cooling (sweating and breathing) could be affected by high humidity [9].

2.4.3 Air velocity

Air velocity between 1.6 m/s to 5.4 m/s is considered as the best performance level [11]. Beaufort scale is used to determine wind speed performance level which is shown in Table 1.

Table 1
The scale for measurement for wind speed

Scale	Description	m sec^{-1}	Condition
0	Calm	<0.3	Calm smoke rises vertically
1	Light air	0.3-1.5	Wind motion visible in smoke
2	Light breeze	1.6-3.4	Wind felt on exposed skin Leaves rustle
3	Gentle breeze	3.4-5.4	Leaves and smaller twigs in constant motion
4	Moderatebreeze	5.5-7.9	Dust and loose paper raised Small branches begin to move
5	Fresh breeze	8.0-10.7	Branches of a moderate size move Small trees begin to sway

2.5 Materials

Not all total energy produced in the developed world is used efficiently for heating and cooling, ventilating and controlling humidity to fulfil the demand of thermal comfort required by occupants. Using latest materials and passive technology systems in buildings would considerably reduce energy demand and improve the impact on the environment. In addition to energy saving, a building's thermal comfort is controlled by factors, comprising building orientation, thermo-physical properties of construction materials, ventilation, building space, and the integration of passive energy saving technologies. The internal thermal comfort is influenced by the thermal properties of the construction materials used and on the external temperature [12].

The thermal properties of the construction materials influence heat and cold transmitted through transparent and translucent materials [13]. Materials with higher thermal resistance, lower thermal diffusivity and absorptivity have been shown to have lower temperature fluctuate on the inside of the walls compared to lower thermal resistance materials.

Many traditional hot-humid buildings use lightweight permeable materials such as wooden walls and woven bamboo strip flooring [14]. The kind of construction will permit the interiors to cool quickly in the evening after the outside temperature drops.

2.6 Ventilation System

A certain rate of air exchange is an extremely important component of comfortable indoor environment and healthy surrounding [15]. Traditionally, ventilation systems have been intended to give thermal comfort and odor control, assuming that air is perfectly mixed in a building.

2.6.1 Natural ventilation

Natural ventilation within buildings is understood as the airflow is naturally produced throughout the construction driven by pressure changes. These changes in pressure or driving forces are predominantly two: wind pressure and buoyancy. Both changes are of the same physical origin, but in various scales. Wind forces and temperature difference between the outside and inside building is a two natural forces available for moving air through and out of buildings [15]. These air movements are depending on building design, location and atmospheric conditions that caused either by forces acting alone or combining by both forces. The author added that seasonal and daily variations in wind velocity and direction, average wind speed and wind interference by structures and other obstruction are the conditions that has to be considered to produce ventilation.

2.6.2 Mechanical ventilation

Air circulation is achieved by the help of mechanical systems such as blower which the required air changes are affected partially by diffusion but mainly by positive currents in motion by electricity [16]. Instead of relying on airflow through small holes or flaws in the walls, roof, or windows of a home, mechanical ventilation systems circulate fresh air using ducts and fans. Dwellers can breathe easier because they know that their home is well ventilated.

3. Results and Discussions
3.1 Temperature

A different data is shown in Table 2 and Figure 3 demonstrating the indoor temperature profile of living room in traditional house is lower compare to modern house at three different hours which is at 10:00, 12:00 and 14:00 hours. At 10:00, the temperature for traditional house is 26.8°C which is in the range of comfort temperature compare to indoor temperature for modern house. The highest indoor temperature obtained at 14:00 hours which is 30.7°C for modern house and 28.5°C for Malay Traditional House at the same hour.

These shows that the temperature is slightly under discomfort temperature level which is usually occurs during afternoon. Indoor temperature usually influenced by outdoor environment temperature. The higher urban temperature in a naturally ventilated residential building has significant implications for the indoor environment. Highest temperature usually occurs at 1400 hour due to the earth's surface warmed when sunlight hits the earth. Atmospheric temperatures are very low before sunrise and temperatures increase along the sunrise.

As stated by Sabarinah and Steven [17], the comfort temperature for all Malaysia building types is in the range of 23.6 °C to 28.6 °C. Research by Zain *et al.,* [18] proposed that temperature below 28.69 °C could be achieved thermal comfort. These comfort temperature range is achieved by Malay Traditional dwelling that still maintaining its own features of traditional house. Another study by Djamila *et al.,* [19] in a thermal comfort survey of the residential building has shown that the acceptable thermal comfort temperature is at 30.2°C and Nguyen *et al.,* [20] stated the thermal comfort limit for building in a hot and humid region is not more than 30°C and Malaysian climate is consistently hot all year.

Table 2
The temperature at traditional and modern house

	Time (hours)	10:00	12:00	14:00
Temperature (°C)	Traditional	26.8	27.7	28.5
	Modern	29.5	30.4	30.7

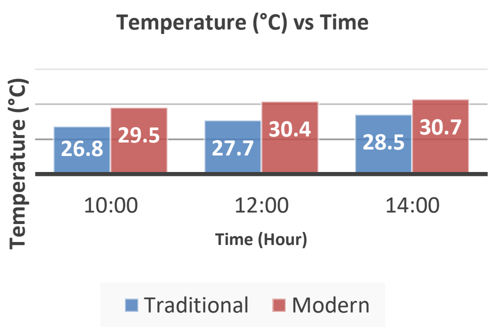

Fig. 3. Temperature data at different time

3.2 Humidity

As shown in Table 3 and Figure 4 the reading for humidity shows that for traditional house is in range of 50% to 59% while for modern house is 65% to 72% which indicate the modern house is slightly humid than traditional house.

As recommended by the Chartered Institute of Building Services Engineers Guide - CIBSE guide, relative humidity must be within range of 40% - 70 % in order to maintain a condition that is comfortable in a hot and humid climate. The maximum air relative humidity of ASHRAE 55-1992 was set at 60 %. This is because, beyond this limit, mold and mildew begin to grow.

ASHRAE 55-1994 tolerated relatively higher humidity to include evaporative air conditioning; whereas ASHRAE 55-2004 did not recommend a lower humidity level. This is because the thermal comfort humidity is insignificant. However, as stated by the same standard, it may have secondary health implications. For example, the increase in evaporation rate may cause skin drying and irritation at low relative humidity.

Table 3
The percentage of humidity at traditional and modern house

	Time (hours)	10:00	12:00	14:00
Humidity (%)	Traditional	59	55	50
	Modern	72	69	65

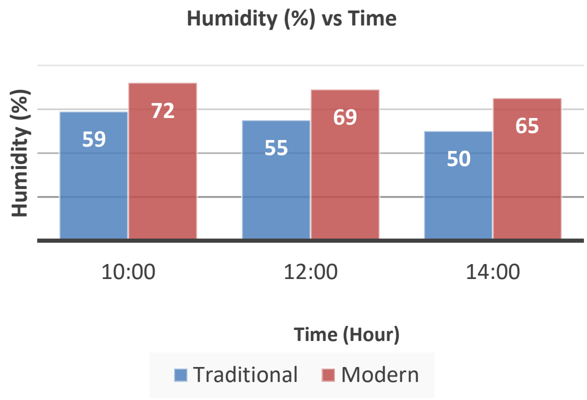

Fig. 4. Humidity percentage data at different time

3.3 Light Intensity

The light intensity data collected at different point and the lux reading for Traditional Malay house is higher compares to the modern house where point A for Traditional house is 205 lux compares to point A in modern house which is 56 lux. For point B, 198 lux for Traditional Malay house and 47 lux for modern house. Meanwhile for point C, Traditional Malay house indicated 87 lux and modern house is 32 lux. The reading for point C is slightly lower for both houses due to the absent of opening at that point and the distance of opening to the point.

The requirement of standard illumination in Malaysian Standard - MS 1525 2001 for typical room is 150 lux to 300 lux and as shown in Figure 5, light intensity in traditional house higher compare to modern house due to its large sizes and number of opening while in modern house shows the reading below 150 lux where low daylight were entering the house and affect the performance and comfort to the dwellers (Table 4). The features in traditional house affect the amount of daylight from the sun enters the house through an opening. Thus, reduce the amount of necessary electric lighting and save cost and energy.

Table 4
The illuminance at specific point in both houses

	Time (hours)	Point A	Point B	Point C
Illuminance (lux)	Traditional	205	198	87
	Modern	56	47	32

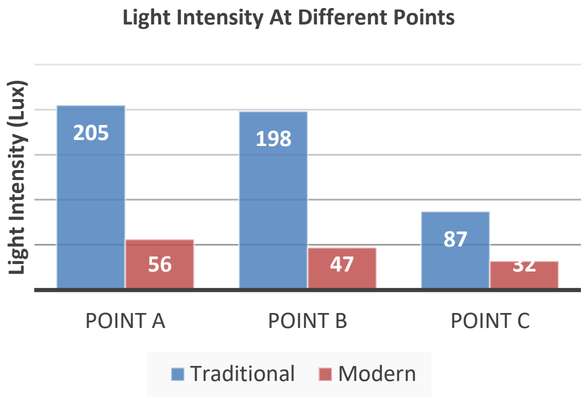

Fig. 5. Comparison of light intensity between two houses

Daylight offers high luminance and allows for exceptional color discrimination and rendering of colours. These two properties mean daylight is the prerequisite for good vision. Daylight can also produce sore glare on display screens, however, and very high luminance reflections, both interfering with good vision. Therefore, the effect of daylight on task performance depends on the delivery of daylight.

3.4 Computer Simulation Work

Figure 6 and 7 shows the air movement inside living room of Malay Traditional house and modern house. The legend in the figure shows the colour that indicated the value of velocity magnitude and the movement of air entering the dwelling. Air velocity of almost 4 m/s entering the Malay Traditional house while. Air velocity between 1.6 m/s to 5.4 m/s is considered as the best performance level [11].

The arrows at the opening shows the movement of air whether it is going in or out and different windows shows different value of velocity magnitude of air entering and leaving the house. The red colour arrow shows the air velocity is between 3.2 m/s to 4 m/s while blue colour shows velocity between 0 m/s to 1.5 m/s which indicate low speed of air moving inside the dwelling. The temperature distribution for the air is taken at a height of 1.5 m above the floor level.

The simulation for Traditional Malay house shows more different velocity value compares to modern house which indicated that there is more air movement occurs. The patterns of air flow inside Traditional Malay house shows that the air flow movement are moving and filling the house spaces while in modern house, the swirling flow intensity appears to be lowest in the area closed to the middle of the house.

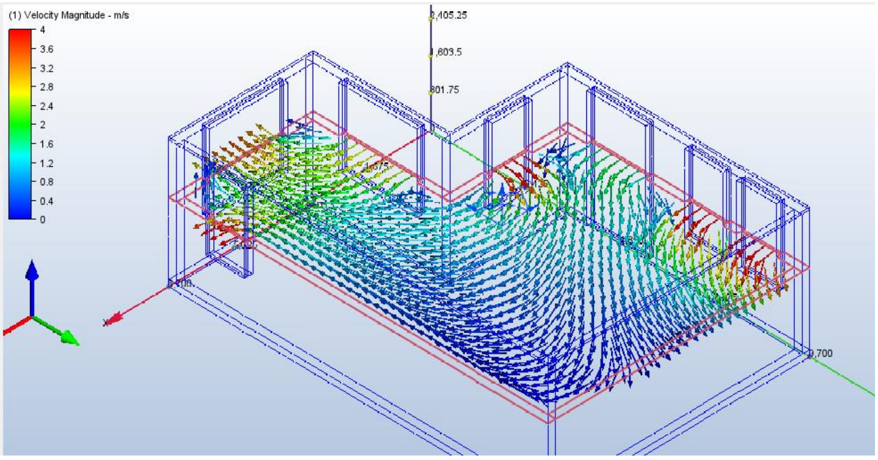

Fig. 6. Air movement in traditional house

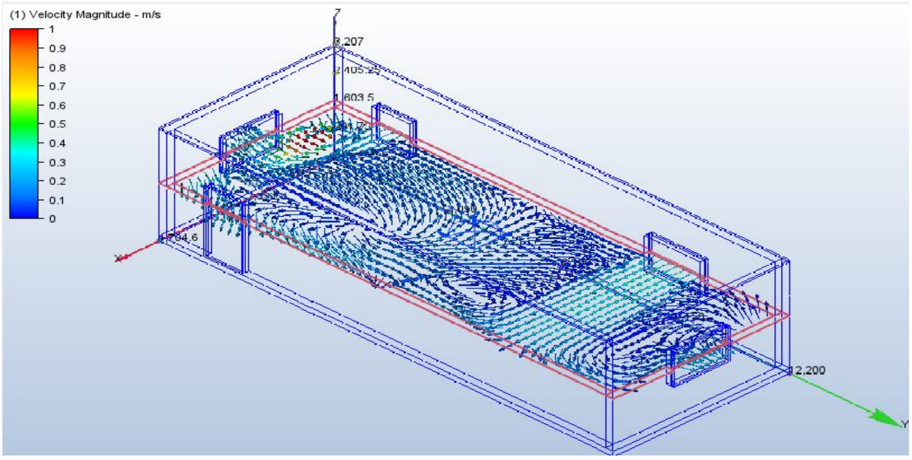

Fig. 7. Air movement in modern house

4. Conclusion

Malay Traditional house has achieved thermal comfort in term of indoor temperature, humidity and air movement that still maintaining its own features of traditional house compared to modern house. The temperature in Traditional Malay house is between 26.8°C to 28.5°C while the modern house is in range of 29.5°C to 30.7°C.

The humidity value for Malay Traditional house is in range of 50% to 59% which conclude that this value is acceptable and thermal comfort according to the ASHRAE standard while modern house has 65% to 72% of humidity which is slightly higher than the standard.

The light intensity for both houses is 87 lux to 205 lux for specific points for traditional house while 32 lux to 56 lux for modern house. For light intensity for modern house, it is lower than the Malaysian Standard - MS 1525 2001 requirement's which is between 150 lux to 300 lux showing that the dwellers need to use additional light or electricity for working.

It is proven that large opening in traditional Malay house can provide good ventilation without depending on mechanical system. AS highlighted by previous researchers, traditional house has been demonstrated that most traditional buildings using passive heating and cooling systems can provide better thermal indoor comfort compared to modern buildings. In addition, in the same bio-climate, these buildings consume less energy than modern buildings.

CFD simulations were carried out on the house's representative models. Using this technique, when it was naturally ventilated, we were able to observe the temperature distribution and air flow conditions within the house. The validation of CFD with experimental data is achieved. CFD simulation result prove that the selected location of ventilation opening can affect the thermal comfort level of a house. The Malays have successfully designed their dwellings for comfort by promoting natural ventilations along with light weight construction materials and other passive design strategies to adapted to Malaysia's climate.

5. Research Recommendation

It is important to know the thermal comfort of dwellers in houses to ensure the dwellers are comfortable in their living spaces. Therefore, an assessment of orientation and opening are crucial. Not only that, knowing the wind direction and wind speed allowed the designer to adapt elements of comfort into designing phases. The re-adapted thermal comfort elements are the consideration of the orientation of the building, the design of the fenestration, the application of the natural lighting system and the natural ventilation system and the arrangement of interior spaces.

For more accurate assessment of thermal comfort issues in tropical climate, further studies on the different urban areas and different cases in Malaysia are recommended.

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