A comparative analysis between traditional Malay house and terraced house in energy conservation

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Abstract. Malaysia’s population has been steadily increasing thus resulting in higher demand in residential housing. Modern housing design perceived as neglecting our local traditions, climate and context, cutting ourselves off from our past architectural heritage, which was highly practical with applications of passive design elements. The traditional Malay houses were exceptionally well designed to suit the warm and humid Malaysian climate and for the multifunctional use of space compared to terraced houses. This research aims to compare the energy conservation between traditional Malay house and terraced house from thermal comfort and lighting perspective. It studies on traditional Malay house (TMH) specifically ‘Rumah Bumbung Panjang’ as representative of climate response building. In contrast, the modern terraced house (TH) was represented by modern building that use artificial and mechanical lighting and ventilation to achieve thermal and lighting comfort. This research bases on data collected using a multifunction anemometer that includes illuminance levels, temperature and relative humidity. The data then tabulated and analysed. The research suggested that adaptation of traditional Malay house architectural elements would increase energy efficiency in terraced houses, thus conserved more energy. It also indicated that traditional Malay house could be easily adapted in the design of modern terraced houses and improved to meet the requirements of modern living.

1. Introduction

The traditional Malay house is a timber house raised on stilts. It is a post-and-lintel structure with wooden or bamboo walls and a thatch roof. Windows are plentiful, lining the walls and providing proper ventilation and views for the house—this quality of openness reflected by the large open interior spaces with minimal partitions [1]. The house is essentially a timber post and beam construction that is lightweight and utilizes one of the earliest prefabrication methods in building construction. Besides being well adapted to the environment, the house has evolved a prefabricated building system that was flexible and varied to suit the needs of the users. It has developed a very sophisticated addition system which allows the house to extended in line with the growing needs of the user [2].

Opposite of the traditional Malay house, terraced housing is the most common housing typology in Malaysia by 40% than any other building typology and it is a medium density type of housing [3]. Terraced houses typically located along the main road, arrange in linear alignments alongside the smaller roads which branch out to another smaller alley. The fenestration is only at the front and back façade. The mixture of colonial heritage and traditional form of housing creates what we know today as modern terraced housing. Style variation immigrants brought their housing styles and adapted it to Malaysian vernacular material and customized it to the tropical climatic condition and developed into various forms, built in the architectural style of international functionalism to accommodate new social and
economic needs [4]. Modern terraced houses built on lesser land than the same number of other types of homes, and this makes them the most suitable types of the house for massive density development that can contribute to the limitation of urban mass [5]. The terraced house is also mimicking the modern western houses that were unsuitable for tropical climates. It focusses on minimal appearance and aesthetics and short-term economic profit neglects passive design, resulting in unsustainable houses that over-rely on mechanical cooling and lighting systems [6].

Moving in line with Malaysia economic development as a developing country, energy consumption in Malaysia has been reported to increase higher growth rates. According to National Energy Balance (NEB), final energy consumption grew averaging between 3% to 4% yearly from 1971 until 2016 and projected for 2017 and beyond [7]. Increment of the population all around the world and demand for residential housing leads to a rise in energy demand and usage. In 2016, residential sector in Malaysia was the main consumer of electricity, and it contributed 21.6% of total electricity consumption, out of which 11% of the total electricity consumed in the residential sector are for space cooling purposes [8].

Energy conservation is the exertion made to lessen the utilization of energy by utilizing less of an energy service [9]. It can be accomplished either by using energy more proficiently or by decreasing the amount of service used. Energy conservation is a part of the concept of Eco-sufficiency. Energy conservation reduces the requirement for energy services and can bring about expanded environmental quality, national security, personal financial security and higher savings [10]. It is at the highest point of the reasonably suitable energy hierarchy. It additionally brings down energy costs by counteracting future resource depletion. Energy conservation in modern terraced houses may differ from traditional Malay houses as the implementation of energy efficiency has become the global trend. It proves to give more benefits and advantages in terms of reducing energy consumption by utilities and equipment in the building, thus reducing the cost of electricity [11]. Energy use by the residential sector makes up about 15% of all energy consumed by all industries in Malaysia and ranks fourth after other significant sectors such as transport, industrial and non-energy [12].

Terraced houses are lacking in natural ventilation as commonly; it has only two or three facades available for openings that contribute to slow and low air exchange in the house. It causes hot air to stay longer, and cold air could not travel efficiently within the building. It also lacks natural lighting. Apart from the house itself, it is designed in the modern style as it does not incorporate passive design techniques that adapt to the environment and allow natural sunlight and wind to enter the building [5]. Usage of artificial lighting also increases the temperature in the building and create an unpleasant and hot environment inside the house that led to an uncomfortable condition and reduce thermal comfort performance.

2. Methodology
The objectives for this research are to identify the current design of terraced house and its relation to energy consumption and to explore measures/components that influences the energy performance of traditional Malay house. For this research, the quantitative method used to determine the outcome of the study. Data were collected using multifunction anemometer and photographs—important information about the buildings such as the location, building design, building condition, etc. Photographic evidence of the house's design was collected so that it can use to compare in data analysis. All necessary design and architecture elements and new retrofits also recorded. From the observation, an early assumption and data have been collected before secondary data will support and confirm it. An extensive literature review has been done and it will be used to assist on data collection. Literature reviews include sources from journals, books, previous researches, articles, websites, etc. For Case Study, the houses chose divided into two types: terraced houses (TH) and traditional Malay houses’ Rumah Bumbung Panjang’ (TMH). TH was in Seksyen U12 Shah Alam while TMH was in Sungai Besar, Sabak Bernam. Both Case Studies were in Selangor.

Data collected using multifunction anemometer were illuminance levels, temperature and relative humidity. The temperature and relative humidity were recorded to analyse the average temperature of TH and TMH to determine their respective thermal conditions and ventilations whether they achieve the thermal comfort and optimum ventilation required by house occupants. The measurement of the illuminance level (lux level) was to determine whether these houses achieve satisfactory levels of
lighting with and without artificial lighting. A various set of data will be recorded in different areas within the house. The data also will be collected in every room within the house proximity. It was done to find average data for the entire house. The data collection will be carried out in three conditions, artificial lighting and mechanical ventilation used (A); natural ventilation/lighting used (B); and combination of both (C). There also limitations, such as areas that have no artificial lighting or mechanical ventilation; therefore, only one data will be collected.

These data also will be recorded at four different times that were 8.00 am, 12.00 pm, 5.00 pm and 10.00 pm. It's because, within this period, the condition of the weather, the position of the sun was varied, thus affecting the data recorded. The physical measurements of parameters were taken at 1.5m height above the floor to obtain accurate result [13]. The selected height is the most suitable for collecting thermal comfort data [14]. An energy audit has been carried out to determine the details of the energy consumption of the building [15]. An indication plan for every house that indicated the data reading point, natural and artificial lighting and natural and mechanical ventilation were drawn. Data collection sheets for illuminance level, temperature and relative humidity were created and provided.

For the analysis of the data, the data for TH and TMH will be compared to Malaysia Standard: Energy Efficiency and Use of Renewable Energy for Residential Buildings - Code of Practice MS 2680:2017 [16] and Malaysian Standard: Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings - Code of Practice (Second Revision) MS 1525:2014 [17].

Table 1. Illumination levels as recommended by MS 2680:2017.

| Area          | Recommended lux (Lux) |
|---------------|-----------------------|
| Living Room   | 200                   |
| Dining Room   | 250                   |
| Kitchen       | 250                   |
| Bedroom       | 180                   |
| Bathroom      | 150                   |

Table 2. Useful daylight illuminance (UDI) range recommended by MS 2680:2017.

| Area                                      | Recommended lux (Lux) |
|-------------------------------------------|-----------------------|
| Useful                                    | 100 to 2000           |
| Below useful (can cause visual discomfort)| <200                  |
| Exceed useful (can cause glare, visual and thermal discomfort) | >2000                 |

Malaysian Standard: Energy Efficiency and Use of Renewable Energy for Residential Buildings - Code of Practice MS 2680:2017 has stated that there are recommended lux levels for different rooms and useful daylight illuminance (UDI) range for the residential building including terraced house and traditional Malay house. The recommended lux for residential building is shown in table 1 and recommended useful daylight illuminance (UDI) range for residential building is shown in table 2:

Malaysian Standard: Energy Efficiency and Use of Renewable Energy for Residential Buildings - Code of Practice MS 2680:2017 and Malaysian Standard: Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings - Code of Practice (Second Revision) MS 1525:2014 have stated that human body temperature needs to be maintained at 37°C ± 0.5°C regardless of ambient condition. MS 2680:2017 used ANSI/ASHRAE Standard 55 [15] adaptive thermal comfort chart, as shown in figure 1 to determine the suitable indoor temperature.
The temperature for each house is different as the daily ambient average temperature is varied. Therefore, there will slight differences in comfortable indoor temperature for every house. It also stated that the most suitable relative humidity for indoor comfort is between 50% to 70% with the assistance of air-conditioner. Malaysia’s climate is 70% to 90% humid around the year, therefore for a building without any air-conditioner, the relative humidity design can be allowed between 50% to 80%.

3. Results and Discussion

Table 3. Data comparison with Malaysian Standards for illuminance level.

| Malaysian Standard MS2680:2017 (Lux) | Terraced House A | Terraced House B | Traditional Malay House A | Traditional Malay House A (Extension) | Traditional Malay House B | Traditional Malay House B (Extension) |
|--------------------------------------|------------------|------------------|--------------------------|---------------------------------------|--------------------------|--------------------------------------|
| Condition                            | A                | B                | C                        | A                                      | B                        | C                                    | A                                      | B                        | C                        |
| Living Room (200)                    | X                | /                | X                        | /                                      | X                        | /                                    | X                                      | X                        | X                        |
| Bedroom (180)                        | X                | /                | X                        | /                                      | X                        | /                                    | X                                      | X                        | X                        |
| Kitchen (250)                        | X                | /                | X                        | /                                      | X                        | /                                    | X                                      | X                        | X                        |
| Bathroom (150)                       | X                | X                | X                        | X                                      | X                        | X                                    | X                                      | X                        | X                        |
| Dining Room (250)                    | -                | -                | -                        | -                                      | -                        | -                                    | -                                      | -                        | X                        |

a Artificial lighting used (A)  
b Natural lighting used (B)  
c Combination of both (C)  
d Not complied to MS2680:2017 (X)  
e Complied to MS2680:2017 (/)  
f Not Available (-)
Table 3 shows a summary of TH and TMH illuminance levels compared to MS 2680:2017. It shows that most of the rooms in TH and TMH complied with the standard. From the perspective of TH and TMH, it shows that both types of houses had a similar result. Most light penetration was allowed in TH and TMH in these two conditions, natural lighting only (B) and a combination of artificial lighting and natural lighting (C) while artificial lighting only (A) does not provide adequate illumination levels in all houses. TMH allows the lightest penetration than the terraced house. It is because of the architectural elements of the TMH that use plenty and large windows, door and opening. Fully openable windows also allowed light to enter easily. Minimal partition and open floor plan allowed light to travel throughout the house easily without any restriction. Even though it will enable more light penetration, it does not cause any glare as the illuminance data collected does not exceed 2000 lux. It is because of large roof overhangs and low windows which excluded the open skies from the visual field. Another reason is also due to vegetation, walls of neighbouring houses that made from wood and the orientation of the house itself. During the night, TMH is considered underlighting because the windows and doors are a solid piece of wood that when close it would allow a little amount of light to enter this it also creates a sense of coolness in the house.

TH has enough natural lighting same as TMH. Similarities of all four houses were that they were underlighting when using artificial lighting only. It may happen due to reasons explained before and it can happen because of mistakes and faulty in designing the lighting design and selection of lamps. For the TMH house extension, it does not comply with the standard because of how it was built. TMH (A) extension was built under the existing TMH (A) and TMH (B) extension was built under and at the back of existing TMH (B). For the Not Available (-) condition, it is because of few factors that were, the current area does not exist within the building and there were no natural or artificial light sources available to conduct data collection.

Table 4. Data comparison with Malaysian Standards for temperature.

| Malaysian Standard MS2680:2017 (°C) | Terraced House A | Terraced House B | Traditional Malay House A | Traditional Malay House A (Extension) | Traditional Malay House B | Traditional Malay House B (Extension) |
|----------------------------------|------------------|------------------|--------------------------|---------------------------------------|--------------------------|---------------------------------------|
| Condition                        | A B C            | A B C            | A B C                    | A B C                                 | A B C                    | A B C                                 |
| Living Room                      | X X X X X X / / / / / X / / / / / X / / / / / X / / |                          |                                        |                         |                                        |                                      |
| Bedroom                          | / X / X X X / / / / / X / / / / / X / / |                          |                                        |                         |                                        |                                      |
| Kitchen                          | - / - - X - - / - - X - - - - - - |                          |                                        |                         |                                        |                                      |
| Bathroom                         | - / - - X - - / - - X - - - - - - |                          |                                        |                         |                                        |                                      |
| Dining Room                      | - - - - - - - - - - - - - - - - - - - |                          |                                        |                         |                                        |                                      |

|                             | a Mechanical ventilation used (A) | b Natural ventilation used (B) | c Combination of both (C) | d Not complied to MS2680:2017 (X) | e Complied to MS2680:2017 (/) | f Not Available (-) |
|------------------------------|----------------------------------|-------------------------------|---------------------------|----------------------------------|---------------------------|-------------------|

Table 4 shows a summary of temperature for every house. Each house was compared to MS 2680:2017 and MS 1525:2014. It shows that most of the rooms in every house complied with the standard. From the perspective of TH and TMH, it shows that both types of houses had similar results. From these tables, it can be determined that the house that has the highest thermal comfort reduce the need for mechanical ventilation such as air-conditioner. All rooms in TMH comply with the standard state in MS 2680:2017 compared to both TH and TMH extension. From using mechanical ventilation or natural ventilation towards the combination of both, TMH was more comfortable than TH. It is because of the architectural elements of TMH that use plenty and large windows, door and opening that
allow for good airflow in the houses. Minimal partition and open floor plan allowed good cross-ventilation without any restriction and even helped from mechanical ventilation. The houses were also built on stilts; therefore, it should increase the airflow and create a much cooler house compared to TH.

For TH, the temperature comply with standard only when using mechanical ventilation or the combination of both conditions. It was due to the usage of limited windows and the placement of the window at only one window per façade and it does not allow for more and better ventilation. Both houses provided the same window for both natural lighting and natural ventilation despite the contradictory nature of the two requirements. Other than that, usage of deep floor plan and partition also restricted the airflow and ventilation compared to TMH. From using mechanical ventilation or natural ventilation towards the combination of both, TMH was more comfortable than TH and the house extensions themselves.

**Table 5.** Data comparison with Malaysian Standards for relative humidity.

| Malaysian Standard MS1525:2014 (50% - 80%) | Terraced House A | Terraced House B | Traditional Malay House A | Traditional Malay House A (Extension) | Traditional Malay House B | Traditional Malay House B (Extension) |
|-------------------------------------------|------------------|------------------|--------------------------|---------------------------------------|--------------------------|---------------------------------------|
| Condition | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| Living Room | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Bedroom | / | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Kitchen | - | X | - | - | X | - | - | X | - | - | - | - | X | - |
| Bathroom | - | / | - | - | X | - | - | X | - | - | - | - | - | X |
| Dining Room | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

* Mechanical ventilation used (A)
* Natural ventilation used (B)
* Combination of both (C)
* Not complied to MS1525:2014 (X)
* Complied to MS1525:2014 (/)
* Not Available (-)

**Table 6.** Data comparison with Malaysian Standards for relative humidity in percentage (%).

| Malaysian Standard MS1525:2014 (50% - 80%) | Terraced House A | Terraced House B | Traditional Malay House A | Traditional Malay House A (Extension) | Traditional Malay House B | Traditional Malay House B (Extension) |
|-------------------------------------------|------------------|------------------|--------------------------|---------------------------------------|--------------------------|---------------------------------------|
| Condition | A | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| Living Room | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Bedroom | 1 | 4 | 3 | 2 | 3 | 2 | 3 | 5 | 4 | 4 | 5 | 4 | 4 | 5 |
| Kitchen | 8 | 8 | 8 | 8 | 8 | 5 | 6 | 5 | 6 | 5 | 6 | 5 | 6 | 8 |
| Bathroom | 0 | 3 | 1 | 3 | 4 | 3 | 5 | 6 | 5 | 5 | 6 | 5 | 6 | 7 |
| Dining Room | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

* Mechanical ventilation used (A)
* Natural ventilation used (B)
Table 5 and 6 shows a summary of relative humidity for every house. The relative humidity stated in MS 1525:2014 is between 50% to 80% and similarities of all four houses were that they do not fully achieve the standard as all houses were over humid as shown in Table 5 and 6. Table 5 shows that only bedroom in TH(A) in when in mechanical ventilation used condition and bathroom when in natural ventilation used condition. Even though TMH had large windows and opening, rainwater does not penetrate because of large roof overhangs compared to TH that have standard sun shading device regardless of sun path. TH also sometimes has no sun shading device at all near the windows affecting the temperature and relative humidity of these houses. Another reason is also because of the housing material; for instance, TMH uses timber that is much cooler compared to a modern TH that uses concrete.

From the data analysis and comparison with MS 2680:2017 and MS 1525:2014, the most energy-efficient and conserving the most energy is Traditional Malay House A (Original House). It is because this house complies with most of the items stated in the Malaysia Standards compare to its house extension and the other three houses. Coming in in second is Traditional Malay House B (Original House) which also complies with the Malaysian Standard. Data analysis shows that TMH uses less energy to achieve optimum lighting and thermal comfort performance that contribute to energy conservation.

4. Conclusion
This research aims to compare the energy conservation between traditional Malay house and terraced house from thermal comfort and lighting perspective. This research also usually focuses on the distinction of energy conservation of typical Malay houses and terraced houses. From contrast, new housing estates in Malaysia are not only severely built in terms of climate but are also contrary to simple thermal comfort and lighting requirements. The current design of terraced houses in Malaysia is mimicking the modern western houses that are unsuitable for tropical climates. It is very minimal and does not contribute to energy efficiency and required assistance from mechanical and artificial retrofitting. Compared to traditional Malay houses that were designed to cater to the needs for comfort using natural elements, a modern terraced house does not use natural features effectively. From the data analysis, it is proven that the architectural elements of traditional Malay houses do affect energy performance. Traditional Malay house has outdone terraced houses in lighting and thermal comfort with the presence of the architectural elements mentioned. It also proves that the features could increase energy efficiency and contribute to less usage of energy retrofit to achieve optimum lighting and thermal comfort compared to terraced houses. Some of the architectural features of traditional Malay houses can be adapted to the design of modern terraced houses that can contribute to energy conservation. These elements must be the best and suitable design for current and future implementation of conventional terraced houses design Malaysia based on the weather condition, climate, culture and capacity of Malaysian people. Further research can be conducted that includes the materials and other traditional design elements of traditional Malay houses such as carvings and ornamentation that could contribute to the energy conservation of modern housing.

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