A review of spatial comfort in shophouse in humid tropics

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Abstract. Shophouse is the most building type built along the road with various commercial
functions. Due to the high rate of land price and the high percentage of building basic
coefficient, therefore the shophouse is commonly built in maximum. This characteristic creates
a lack of apertures through the buildings due to being trapped by surrounding shophouses.
Shophouses are also built in heavyweight construction, i.e., concrete and brickwork. Due to
such limitations, this study aims at assessing the spatial comfort of the shophouse; i.e., thermal
and lighting. It is quite visible that quality. This study was carried out through the field
measurement. Taking Banda Aceh climate as the case study in humid tropics, this study found
that the high inside air temperature mostly runs throughout the upper floor during the day, and
the ground floor during the night; and the small value of daylight occurs almost on the entire
rooms during the day. This paper further proposes the possibility to improve the comfort
quality in the shophouse which is conducted through the literature survey.

1. Introduction
Shophouse is the most building type built along the road with various mix-use functions. Due to the
high rate of land price and the high percentage of building basic coefficient, therefore the shophouse is
commonly built in maximum size. This characteristic creates a lack of apertures through the buildings
due to being trapped by surrounding shophouses. Shophouses are also built in heavyweight construction, i.e., concrete and brickwork [1,2]. In humid tropics area such as Indonesia, thermal comfort is an essential need to be provided along with the building construction. Most of the shophouses use air-conditioner (AC) to provide cool air; therefore, it shows that there is lack of thermal comfort. Due to the maximum use of land, shophouses are commonly built with limited openings and ventilation; therefore, the electrical light is also widely used during the day.

As in the other city, the main roads in Banda Aceh are majorly surrounded by shophouses. The
town is further developed with some new roads which are also followed with various new shophouses.
The characteristics of the shops as previously described are built densely with heavyweight
construction. The facade is designed with high surface temperature material [3]. With some problems
firstly discussed the use of energy in providing cool air and light into the shophouse will be
continuously excessive if there is not an intervention to reduce the energy use. In studying this
phenomenon, this study reviews two different shophouses in some dense areas in Banda Aceh. The
aim of this study is to assess the quality of thermal and lighting comfort in the shophouses which was evaluated through field survey, and to find the solution through literature review.

2. Spatial Comfort
Spatial comfort from the perspective of architectural science includes thermal comfort, adequacy Light and room acoustic [4,5]. In tropics for home cases room, acoustic is not a matter. Therefore thermal and lighting are mainly reviewed. According to ASHRAE Thermal comfort in the building is a condition that expresses satisfaction with the surrounding environment [6]. Factors influencing it are air temperature (°C), mean radiant temperature (°C), air velocity (m/s), relative humidity (%), human activity level (Metabolic Rate) and the type of clothing worn (Clo). Comfort temperature all over the globe is different which is depending on the average daily outdoor temperature (Td). Karyono collected some thermal comfort studies in Indonesia and from those found a regression equation of predicted comfort temperature (PCT) for Indonesia on the mean daily outdoor temperature as follows [7]:

\[ PCT = 0.749Td + 5.953 \] (1)

PCT is the predicted comfort temperature, and Td is the average daily outdoor temperature. The coefficient determination of \( R^2 = 0.38 \) (\( r = 0.61 \)), and the regression is significant at a 95% confidence level. For Banda Aceh where the average daily outdoor temperature (Td) is 27.5°C; while the maximum, and minimum value are 31.8°C; and 23.2 °C respectively, therefore the comfort temperature range following formula 1 is as shown in table 1.

| Td     | Min (°C) | Avg (°C) | Max (°C) |
|--------|----------|----------|----------|
| Td     | 29.7     | 23.4     | 26.6     |

To bring thermal comfort in the tropics with warm moist character, it needs to remove the excessive heat through adequate ventilation. Stilt building is required in this area to capture the wind that moves faster above the average height of the building. Buildings are made of lightweight construction with apertures facing north and south [4]. Another factor of spatial comfort is lighting. Lighting is a process, a way, the act gives light. Light is a prerequisite for human vision, especially in recognizing the environment and run activities. The object that we see is the reflection of light from the object. Therefore, how we view and respond to our surroundings depends on the type of lighting used. There are fundamental differences between the light and illumination. Lighting emphasizes the properties of radiation that must be considered in designing interior. The application of good lighting cannot be separated from the optimal use of natural light and artificial efficient. While the light makes the room bright, it also brings the heat which can contribute discomfort. Therefore unwisely designing large apertures will refer to energy waste. On the other hand, poor lighting can make it difficult to respond around, whereas excessive exposure can lead to glare (glare) so that users are not comfortable during the day. It is necessary to present the building which is convenient for the user visually, at the same time it also needs a proper consideration for the light coming without bringing excessive heat effects. In this study, the illumination (lux) of the daylight is measured. Illumination is the intensity, as perceived by the human eye, of light that hits or passes through a surface. The recommended standard of illumination for shophouse with ordinary activities, i.e., homes, warehouse and routine office work is 120-500 lux [10].

3. Research Method
This study is a quantitative work which was developed through field measurement and literature review. Due to the limitation of the tool, the field measurement was limitedly conducted only to air
temperature and relative humidity recorded for 1-3 days; air velocity and illuminance which were recorded for 1 hour alone during the day. The inside measured data were compared with the outside data. The measuring tool utilized is thermal data logger, wind speed meter, and lux meter. This study assessed two type of shophouse which has the same pattern namely built-in row. House-type A is located in suburban while the house-type B is in urban which is closed the CBD (Central Business District) area of Banda Aceh. The two house is built of brick and concrete.

**Figure 1.** Location of the two houses measured in the study

Type A is the shophouse that is utilized as an office on the ground floor and as the house on the second floor (figure 2). It is located in Darussalam where the location is slightly dense. Type 2 is the house built by NGO in 2005 for tsunami survivors which resemble shophouse. This two-story house is built in a row attached to each other. Some people utilize the ground floor as business space and the second floor as the bedroom, while most of the people reside the entire area as homes (figure 2). The house is designed differently from the first type where the roof is pitch roof. The living room has high ceiling intended as a void connecting the upper ceiling to the bedroom on the upper floor. This house is located in Peunayong which is a highly-density living area. These two house types were measured at different time. Thus, the analysis assessed the inside thermal parameters of each house related to the outside thermal parameters during its measurement.

**Figure 2.** a. Shop house-type A  b. Shophouse-type B

### 4. Result and Discussion

The spatial comfort data collected from the survey are shown in table 2. It shows that the two shophouses have the same pattern of air temperature that the inside air temperature during the night is significantly higher than the inside air temperature. This can be understood that the brickwork and concrete wall act as the thermal mass which releases the heat during the absence of the sun into the interior. The condition is worse due to the building attached to each other in a long row. The closed apertures during the evening and night also promote such discomfort because of the absence of adequate airspeed. However, table 2 shows that shophouse-type A has higher inside air (Ta), relative
humidity (RH), and airspeed compared with the value of shophouse-type B. The condition may emerge due to the opaque shape and flat roof of shophouse-type A aggravated by limited apertures which are only accessed from the front and the rear. No roof shading the apertures also creates the discomfort. Shophouse-type B with more openings on the top wall as well as the front and the rear wall creates more paths for circulating air. The gable roof also promotes less inside air temperature compared with the flat roof. Illuminance was also recorded which was measured within 11 am to 3 pm during the measuring period. Shophouse-type A gained 53 lux of the average illuminance which does not meet the requirement which is at least 120 lux should be in homes space. While shophouse-type B can receive 137.6 lux which meets the illuminance standard for homes space.

| Thermal parameter | House-type A | House-type B | difference |
|-------------------|--------------|--------------|------------|
| Inside            | Outside      | difference   | Inside      | Outside      | difference |
| Ta- avg (°C)      | 33.25        | 28.5         | 4          | 31.5         | 29          | 2.5        |
| Ta- max (°C)      | 35           | 33           | 2          | 34           | 33          | 1          |
| Ta- min (°C)      | 31.5         | 24           | 6          | 29           | 25          | 4          |
| RH - avg (%)      | 49.52        | 64.95        | -15.43     | 54.67        | 63.1        | -8.43      |
| RH- max (%)       | 44.92        | 50.22        | -5.3       | 47.49        | 50.22       | -2.73      |
| RH- min (%)       | 54.67        | 84.73        | -30.06     | 63.1         | 79.81       | -16.71     |
| Av (m/s)          | 0.4          | 2            | -1.6       | 1.7          | 3.21        | -1.51      |
| Illuminance (lux) | 53 Bright    | N/A          | 137.6      | Bright       | N/A         |

Although the thermal performance of shophouse-type B is slightly better compared with shophouse-type A, both shophouse types perform higher air temperature correlated with the predicted comfort temperature (table 1). It, therefore, needs some other strategies to create better spatial comfort in the shophouse.

5. Design Strategies
To find the solutions in providing sufficient and comfortable thermal and lighting parameters some relevant studies are discussed. The reviews are grouped into three characteristics, namely courtyard design; aspect ratio of the road and the verandah; and optimal roof design and vertical greeneries.

5.1. Courtyard design
Khan Ly in his study on shophouse in Hanoi found that tube house which is similar to shop house type commonly built; the courtyard has been approached by the ancient people to obtain the comfort [11]. Figure 3 shows that tube house or long narrow building has been separated by the courtyard which can improve the quality of spatial comfort, i.e., cooling and lighting.

![Figure 3. Courtyard in ancient tube house in Hanoi [11]](image)

Even though Hanoi has the warm-humid sub-tropical climate, this design is significantly suitable to be applied in shophouse design in tropics such as Banda Aceh and extensively across Indonesia. The courtyard will let the air move throughout the house plan. The high inside air temperature will be solved through the shade from the vegetation planted in the yard and the shade from the next rooms.
The comfortable daylight also can be extensively achieved through the shaded openings along the rooms.

In Malacca, Malaysia such study on traditional Chinese Shophouses (CSHs) was conducted by Kubota et al. [12]. They investigated indoor thermal conditions in traditional Chinese shophouses (CSHs) in Malacca, Malaysia, using field measurements and focuses on the cooling effects of courtyards. The results indicate that the indoor air temperature in the living rooms of CSHs was approximately 5-6°C lower than the outdoor temperature during the day primarily due to structural cooling effects with night ventilation, whereas the indoor air temperature at night was similar to the outdoor temperature. If the thermal adaptations of the occupants were considered, then the thermal conditions in the living rooms were acceptable for most of the day. The results indicate that the front courtyards functioned as a cooling source for the surrounding spaces in the CSHs. Kubota also found through his comparative study between the traditional Malay house and traditional masonry Chinese shophouse that the small courtyards which are commonly built in Chinese shophouse were effective to cool the high thermal mass structures through nocturnal ventilative and radiative cooling [1].

5.2. Aspect ratio of the road and the verandah
To gain thermal comfort in the shophouse can also be obtained through the aspect ratio of the road and the verandah. The narrower road can lead to the better thermal environment. In a case of the height of the beside building is 15 m, the road with 12 m-to-15 m’s width (or the aspect ratio at 1 to 1.25) will conduct a comfortable microclimate. A more extensive verandah will also form a more comfortable microclimate [13].

5.3. Optimal roof design and vertical greeneries
Designing roof either through color, material or the form will affect indoor thermal performance. Emmanuel through his study found that white roof or roof insulation combination can reduce indoor air temperature up to 3°C [14]. The white roof is also an efficient roof in reducing the effect of the urban island [15]. Building houses with apertures should consider a higher ceiling to cool down the inside air temperature. A higher ceiling can reduce the energy use since it has smaller vertical temperature gradients once the zone is occupied. A higher ceiling will allow greater ventilation is, therefore, allowing the room to meet thermal comfort level [16]. Pitch roof as evidenced in the case study works effectively in reducing the heat gain. It can decrease the inside air temperature down to 1°C [8]. In Singapore, the shophouses are built with jack pitch-roofs for natural light and ventilation for cooling down the microclimate (Figure 4.B) [17].

Figure 4. A. White roof for reflecting solar radiation [18]. B. Shophouses in Singapore with jack pitch-roofs [17].

Roof materials can be approached through Green roof which is also broadly known as the easiest way to reduce the air temperature. Green roof (the plants and the soil) can absorb 60% of the total solar radiation, and only 27% is reflected [19]. The heat and light absorption works for the greeneries life on the roof which means automatically less heat radiated into the interior. Further, optimal use of greeneries around the building such as vertical garden also works efficiently in providing internal thermal comfort. Vertical greeneries also has the ability in producing fresh social space through the rise buildings [20].
5. Conclusion

Shophouse is the most building type built along the road with various mix-use functions configured in the limited land. Through field survey such limitations in humid tropic zones evident to emerge spatial discomforts such as high inside air temperature and relative humidity, low air velocity and poor illuminance. Some literature reviews provide some design strategies to cool down the microclimate. The use of courtyard as inherited in Chinese shophouse design is effective as a cooling source for the surrounding spaces in the shophouse as well as the void for searching the daylight. The aspect ratio of the road and the verandah also influence the spatial comfort in shophouses. The narrower road with the aspect ratio at 1 to 1.25 can lead to the better thermal environment. Roof design also works to create good spatial comfort. Whitening and greening the roof are the strategies to reduce the heat radiated into the interior. Vertical greeneries is also an excellent choice to cool down the microclimate of the shophouse which tends to be modified and expanded vertically. This study recommends further studies to analyze the cooling strategies in the shophouse design extensively by simulating them with thermal analysis software or through experiments.

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