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# Thermal Comfort in Kobuang Limo House: Evaluating Tropical Architectural Elements

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**Abstract**

This study investigates the effectiveness of tropical architectural elements in maintaining thermal comfort in the *Kobuang Limo House*, a traditional Malay dwelling in Riau, Indonesia. Employing an embedded mixed-method approach, the research integrates field measurements and interviews with climate-based simulations. Thermal comfort was evaluated using Effective Temperature (ET), based on SNI 03-6572-2001, incorporating air temperature, humidity, and wind speed. A three-day field measurement in December 2024 showed that the hipped roof, *singap* ventilation, wall openings, and raised floors contributed to passive cooling, although corrugated zinc roofing increased indoor temperatures during the day. To extend the analysis over an annual cycle, statistical monthly climate data from BMKG were used in combination with deviation-based correction factors to simulate indoor conditions. Results indicate that ET values remained within the optimal to slightly warm comfort categories throughout the year, with peak values observed in bedrooms and kitchens during the dry season. The findings emphasize the adaptive performance of tropical architectural design and suggest improvements in insulation and cross-ventilation strategies.

**Keywords**: *Riau Malay house; thermal comfort; tropical architecture; vernacular architecture*

## Introduction

The *Kobuang Limo House*, a traditional Malay Riau house, represents an architectural adaptation to the humid tropical climate, characterized by high temperatures and humidity. Previous studies have found that traditional houses in Indonesia effectively maintain thermal comfort for their occupants as a response to tropical environmental conditions, aligning with the standards set by ASHRAE-55, SNI, and Mom and Wiesebron. (Arman Susilo & Eddy Prianto, 2023).

As part of tropical architecture, these buildings are designed to respond to the characteristics of a tropical climate, which include high humidity levels of up to 90%, temperatures ranging from 15–35°C, intense solar radiation, and annual rainfall exceeding 3000 mm. These factors significantly impact thermal comfort and the physical conditions of occupants. (Karyono, 2016).

Tropical architecture is designed to optimize thermal comfort without relying on artificial cooling systems. Key architectural elements, such as roof shape, natural ventilation, raised floors, and low thermal conductivity materials, play a crucial role in temperature regulation and air circulation within the house. Previous studies indicate that traditional Malay Riau houses employ distinct architectural strategies to adapt to tropical environmental conditions. However, specific studies on the effectiveness of tropical architectural elements in the *Kobuang Limo House* remain limited.

This study aims to identify the tropical architectural elements implemented in *Kobuang Limo House* and analyze their contribution to maintaining thermal comfort in this traditional house in Riau.

## Literature Review

### 1. Principles of Tropical Architecture

Tropical architecture is designed to enhance thermal comfort by optimizing air circulation and protecting buildings from solar radiation and heavy rainfall. (Bambang & Sari, 2021). The key factors determining thermal comfort are humidity, temperature, and air movement. Therefore, building design must naturally adapt to the conditions of a tropical climate. (Pradipto & Marcillia, 2019).

One of the key strategies in tropical architecture is the use of a steep roof with wide eaves, which allows rainwater to drain quickly, reduces the risk of leakage, and minimizes heat penetration into the building (Rivaldy & Utomo, 2024). Additionally, opposing wall openings are designed to create effective cross-ventilation, allowing hot air to be expelled more efficiently and maintaining good indoor air quality (Permadi et al., 2024). Beyond the roof and openings, the raised floor is also a crucial element in tropical architecture, as it helps reduce ground moisture, protects against flooding, and enhances air circulation beneath the building, contributing to indoor cooling (Mufidah et al., 2023).

In addition to form and structure, material selection also plays a vital role in maintaining thermal comfort. The use of wood, lightweight bricks, and porous concrete helps reduce heat absorption and supports natural ventilation, allowing buildings to minimize reliance on artificial cooling systems. (Handoko & Ikaputra, 2019).

### 2. Tropical Architecture in the Context of Traditional Malay Riau Houses

Based on the principles of tropical architecture, traditional Malay Riau houses feature a steep roof with a high ridge to withstand heavy rainfall and strong winds. Tall windows with carved or louvered ventilation panels enhance natural air circulation, helping to maintain indoor cooling. (Faisal & Firzal, 2020). The raised floor serves not only as protection against flooding and ground moisture but also enhances the structural resilience of the building to surrounding environmental conditions. (Samra & Imbardi, 2018). The building materials of these traditional houses are generally made of wood using nailless frame construction, which provides greater flexibility and resistance to environmental changes. (Zain et al., 2021).

The implementation of these elements demonstrates how tropical architecture has been adapted into traditional buildings, making them more energy-efficient, environmentally responsive, and capable of providing optimal thermal comfort for their occupants. Thus, this study will examine the relationship between four tropical architectural elements in Malay Riau houses—roof shape, wall openings and ventilation, raised floors, and building materials—with three key factors influencing thermal comfort: temperature, relative humidity, and air velocity.

### 3. Thermal Comfort

The purpose of applying tropical architectural principles is to achieve thermal comfort within buildings located in tropical climates. According to ANSI/ASHRAE (2017)Thermal comfort is the level of human satisfaction with thermal conditions, which is subjective and influenced by physiological responses to the environment. In line with this, Tri Harso Karyono defines thermal comfort as a state of balance between the human body temperature and the surrounding environmental temperature. (Munawaroh & Elbes, 2019).

This comfort is influenced by environmental factors such as heat conduction, solar radiation, air movement, and evaporation. Naturally, the body's metabolism works to maintain thermal balance, but significant temperature fluctuations can cause both physical and psychological discomfort. (Nugroho & Iyawati, 2021).

In Indonesia, the standard for thermal comfort in building design is regulated by SNI 03-6572-2001, which uses Effective Temperature (ET) as the primary reference. This standard categorizes thermal comfort levels into three ranges based on Effective Temperature:

- Cool Comfortable Category: Effective temperature ranges between 20.5°C to 22.8°C.
- Optimal Comfortable Category: Effective temperature ranges between 22.8°C to 25.8°C.
- Warm Comfortable Category: Effective temperature ranges between 25.8°C and 27.1°C.

SNI defines Effective Temperature (ET) as an environmental index that integrates temperature and humidity into a single value. This index indicates that at a given ET, the human thermal response remains the same, even if the actual temperature and humidity levels differ, as long as the air velocity remains constant.

Effective Temperature (ET) is a linear equation based on the relationship between air temperature, wind speed, and relative humidity, which is then adapted as an analytical tool for assessing thermal comfort in both hot and cold environments. (Blazejczyk in Coccolo et al., 2016). Furthermore, Effective Temperature (ET) can be calculated using the following equation,

$$\mathrm{ET} = 37 - \frac{37 - \mathrm{T}}{0.68 - 0.0014\mathrm{RH} + \frac{1}{1.76 + 1.4\mathrm{V}^{0.75}}} - 0.28\mathrm{T}(1 - 0.01\mathrm{RH})$$

ET = Effective Temperature

37 = Maximum body temperature of a healthy human (°C)

T = Air temperature (°C)

RH = Relative humidity (%)

V = Air velocity (m/s)

This formula will be used in this study to determine the Effective Temperature (ET) value, which will serve as a benchmark for assessing thermal comfort in greater detail.

## Methodology

This study employs an embedded mixed-method approach that combines field measurement with climate-based simulation. The qualitative aspect includes observations and interviews with occupants, while the quantitative aspect consists of direct environmental measurements and secondary data modeling. Measurements of temperature, relative humidity, and wind speed were conducted over three days (10–12 December 2024) in the morning, afternoon, and evening. Data were collected at multiple indoor and outdoor points.

Due to the limited measurement duration, this study introduces a climate-based correction method. Monthly weather data from BMKG representing the year 2024 were used to simulate indoor temperature and humidity using a linear correction factor derived from the three-day measurement ratio. The simulation provides projected Effective Temperature (ET) values for each month, improving the generalizability of the thermal comfort assessment.

## Result and Discussion

This section presents the analysis of tropical architectural elements in the traditional Malay Riau *Kobuang Limo* house in Desa Pulau Belimbing, using an embedded mixed-method approach. Qualitative findings from observations and interviews are supported by quantitative data, including physical element measurements, temperature, humidity, and wind speed, which are then summarized into Effective Temperature (ET). This analysis evaluates how architectural elements contribute to the thermal comfort of the occupants.

**1. Roof Form.**

The *Kobuang Limo House*, also known as Rumah Limasan, features a hipped roof with *singap* ventilation at the top. In the examined sample, the roof has a 30° slope, a height of 2.10 meters, and eaves extending 1.10 meters, which contribute to air circulation and weather protection.

**Figure 1.** Documentation of *Kobuang Limo* House
Source: Author

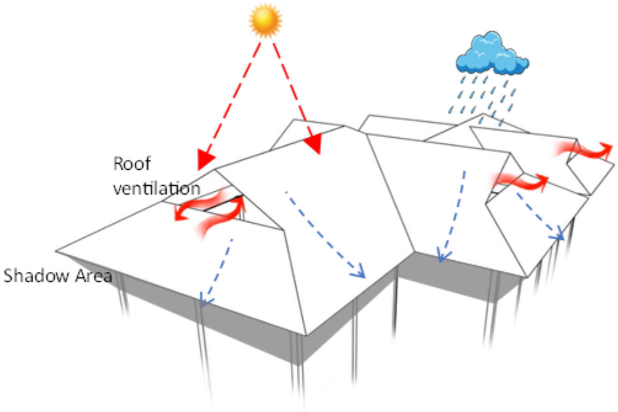



**Figure 2.** Hipped roof sistem of *Kobuang Limo* House
Source: Author

The hip roof with *singap* ventilation is an ideal form in tropical architecture, as it effectively shields all building walls from direct sunlight and heavy rainfall. The optimal roof slope facilitates rapid rainwater runoff, preventing leaks and enhancing structural durability. The presence of *singap* ventilation allows trapped hot air in the space between the roof and ceiling to escape naturally, promoting better air circulation. This system helps maintain a cooler indoor temperature.

Thermal measurements conducted over three days (December 10–12) revealed findings related to the roof form. The average daytime temperature outside the building was recorded at 30.80°C, while inside the house, it was 30.36°C, indicating a temperature reduction of 0.44°C (1.43%).

**Table 1.** Average Temperature of *Kobuang Limo* House

| LOCATION | 10 - 12 December 2024 | | |
|---|---|---|---|
| | **Morning** | **Noon** | **Night** |
| Outside the House | **27.27** | **30.80** | **27.13** |
| Average In House | **27.07** | **30.36** | **26.77** |
| Temperature Deviation | 0.19 | 0.44 | 0.36 |
| Percentage Deviation | 0.71% | 1.43% | 1.33% |

Source: Author Analysis

## 2. Wall Openings and Ventilation

The openings and ventilation in the building envelope of *Kobuang Limo* House are designed as part of a natural ventilation system, enabling optimal air circulation. These openings allow fresh air to enter while expelling hot air, creating a continuous airflow movement. This design supports the principles of cross-ventilation and natural convection.

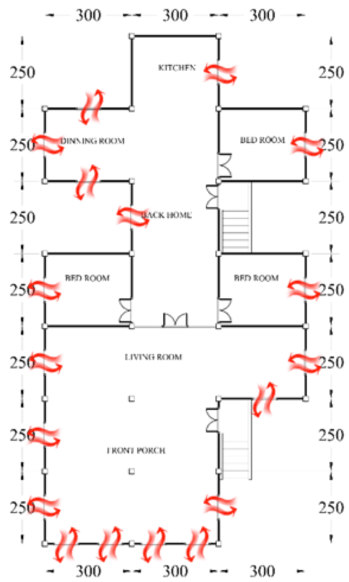



**Figure 3.** Wall Openings layout in *Kobuang Limo* House
Source: Author

**Figure 4.** Entrance Door of *Kobuang Limo* House
Source: Author

The door in *Kobuang Limo House* measures 0.8 × 1.8 meters and consists of two panels, allowing for flexible openings to accommodate air circulation and ventilation needs. This design also saves space when opened, ensuring it does not interfere with the interior layout.

**Figure 5.** Window with Louvers in *Kobuang Limo* House
Source: Author

The windows in *Kobuang Limo House* measure 0.8 × 1.8 meters and consist of two shutters equipped with louvers, allowing air circulation to continue even when the windows are closed. At the bottom, there is a wooden rail that serves as a space divider and safety feature without obstructing airflow. This window design effectively supports natural ventilation.

**Figure 6.** Window with Louvers in Kobuang limo house
Source: Author

The *singap* ventilation on the triangular-shaped roof is installed at each intersection of the hipped roof structure. This ventilation allows trapped hot air above the ceiling to escape, reducing heat buildup and preventing high temperatures from affecting the thermal comfort of the space below. This design supports the principle of passive ventilation, enabling more efficient natural airflow within the building.

The comparison of wall opening area to floor area in *Kobuang Limo House* can be seen in the table below.

**Table 2.** Wall Opening Area in *Kobuang Limo House*

| Room | Floor Area (m2) | wall opening area (m2) | Percentage of Openings to Floor Area (%) |
|---|---|---|---|
| Porch and Living Room | 54.00 | 14.8 | 27% |
| Bed Room 1 | 8.00 | 1.44 | 18% |
| Bed Room 2 | 8.00 | 1.44 | 18% |
| Bed Room 3 | 8.00 | 1.44 | 18% |
| Rear Porch, Dining Room, and Kitchen | 40.00 | 8.88 | 22% |
| **Total Area** | **118.00** | **28** | **24%** |

Source: Author Analysis

The table above shows that the total wall opening area in this building reaches 24% of the floor area, exceeding the minimum standard of SNI 03-6572-2001, which is 5%. The veranda and central room have the highest percentage of openings (27%), allowing maximum airflow in the main area. Bedrooms 1, 2, and 3 have 18% openings, which are sufficient to support natural ventilation in private spaces. Meanwhile, the rear veranda, dining area, and kitchen have 22% openings, facilitating air circulation in the service areas. Overall, the distribution of openings in this building is designed to maximize cross-ventilation and enhance the thermal comfort of occupants.

The effect of the wall opening area is reinforced by the average indoor airflow, as shown in the table below.

**Table 3.** The average airflow in *Kobuang Limo House*

| LOCATION | 10 - 12 December 2024 | | |
|---|---|---|---|
| | Morning | Noon | Night |
| Outside the House (m/s) | **0.27** | **0.33** | **0.10** |
| Average In House (m/s) | **0.06** | **0.16** | **0.03** |
| Velocity Deviation (m/s) | 0.21 | 0.17 | 0.07 |
| Percentage Deviation | 77.50% | 52.00% | 73.33% |

Source: Author Analysis

The table above shows that:

- The average airflow in the morning was recorded at 0.27 m/s outside the house, while inside, it was 0.06 m/s, which is 22.5% of the outdoor airflow conditions.
- The average airflow during the day was recorded at 0.33 m/s outside the building, while inside, it was 0.16 m/s. This indicates that the opening system in Kobuang limo house allows 48% of the outdoor airflow to enter the building.
- The average airflow at night was recorded at 0.1 m/s outside the building, while inside, it was 0.03 m/s. This indicates that, even with windows and doors closed at night, 26.7% of the outdoor airflow still enters the building. This helps prevent excessive thermal decline during nighttime.

### 3. Raised Floor

The raised floor in *Kobuang Limo* House is a distinctive Malay architectural element designed to adapt to Riau's humid tropical climate. With a height of 2.1 meters, this design reduces moisture by minimizing direct contact between the building and the ground, while allowing air circulation beneath the house to maintain a stable indoor temperature. Additionally, the raised floor serves as protection against seasonal flooding and potential threats from wild animals, reflecting an adaptive strategy to the local environment. Thus, the raised floor not only enhances thermal comfort but also represents local wisdom in creating a safe and sustainable dwelling.

**Figure 7.** Window with Louvers in Kobuang limo house
Source: Author

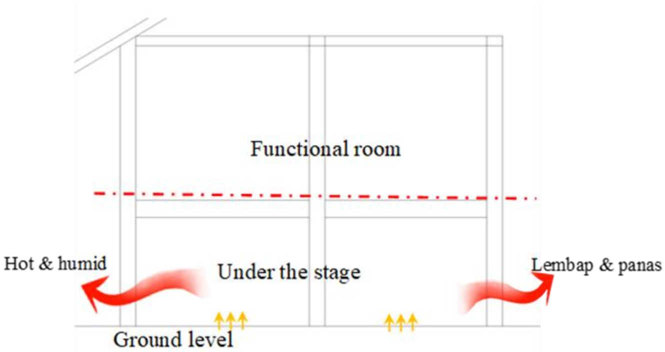



**Figure 8.** Thermal Conditions Beneath the Raised Floor
Source: Author

The raised floor in *Kobuang Limo House* is a distinctive Malay architectural feature, designed to adapt to Riau's humid tropical climate. With a height of 2.1 meters, this design reduces moisture by minimizing direct contact between the building and the ground, while also allowing air circulation beneath the house to help maintain a stable indoor temperature. Additionally, the raised floor serves as protection against seasonal flooding and potential threats from wild animals, reflecting an adaptive response to local environmental conditions. Therefore, the raised floor not only enhances thermal comfort but also represents local wisdom in creating a safe and sustainable living space.

Quantitatively, the effect of the raised floor on humidity levels in Kobuang limo house can be seen in the table below.

**Table 4.** The average Humidity in *Kobuang Limo House*

| LOCATION | 10 - 12 December 2024 | | |
|---|---|---|---|
| | **Morning** | **Noon** | **Night** |
| Outside the House | **73.67** | **59.00** | **80.67** |
| Average In House | **73.60** | **54.60** | **80.53** |
| RH Deviation | 0.07 | 4.40 | 0.13 |
| Percentage Deviation | 0.09% | 7.46% | 0.17% |

Source: Author Analysis

Interview results indicate that the space beneath the Kobuang limo house serves not only as an element of climate adaptation but is also utilized for social activities such as gathering with neighbors, as well as for storage. Homeowners stated that the increased height of the underfloor space enhances comfort, particularly in hot weather, as it allows for more optimal air circulation, thereby helping to maintain a cool temperature inside the house.

**4. Building Materials**

*Kobuang Limo House* uses local materials as a form of adaptation to the humid tropical environment. Over time, the roof material has changed from using palm leaves to corrugated iron, which has a significant impact on thermal comfort.

**a) Roof**

- Material: Corrugated zinc (0.35 mm)
- Thermal Conductivity Coefficient: 113 W/m·K
- Analysis: Zinc has high thermal conductivity, causing an increase in indoor temperature, in contrast to thatch (~0.05 W/m·K), which is more effective in inhibiting heat.

**b) Wall**

- Material: Local wood board (24 mm)
- Thermal Conductivity Coefficient: 0.12 W/m·K
- Analysis: Local wood (kulim & meranti) has good thermal insulation properties, reducing heat transfer from outside to inside, thus increasing thermal comfort.

**c) Floor**

- Material: Kulim wood board (24 mm)
- Thermal Conductivity Coefficient: 0.12 W/m·K
- Analysis: The raised floor (1.6–2.1 m) functions as natural insulation, reducing heat and moisture transfer from the ground, and allowing passive ventilation.

**d) Ceiling**

- Material: Kulim wood board (24 mm)
- Thermal Conductivity Coefficient: 0.12 W/m·K
- Analysis: The raised floor (1.6–2.1 m) functions as natural insulation, reducing heat and moisture transfer from the ground, and allowing passive ventilation.

Changing the roof material to corrugated iron increases the heat inside the house, which is contrary to the principles of tropical architecture. Further studies are needed to optimize the thermal adaptation strategy in this traditional building.

**5. Effective Temperature in Limo Kobuang House.**

To test the thermal comfort of *Kobuang Limo House* related to the three points explained above, the Effective Temperature (ET) analysis is used concerning the SNI standard. Effective temperature integrates air temperature (T), relative humidity (RH), and air flow (V) as the main indicators in assessing thermal conditions in a humid tropical climate. With relatively stable temperatures, humidity often exceeding comfortable limits, and low air flow, this analysis evaluates the effectiveness of the architectural adaptation of *Kobuang Limo House* to the tropical environment.

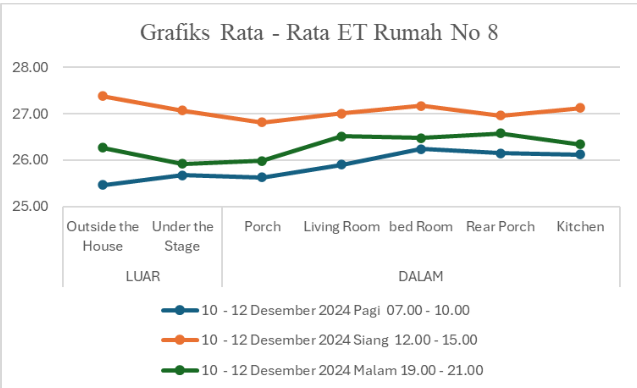
Measurements of air temperature, relative humidity, and air flow for three days (10–12 December 2024) were converted into Effective Temperature (ET) using the formula explained previously to evaluate the effectiveness of tropical architectural elements in maintaining thermal comfort, regarding the SNI 03-6572-2001 standard as a recognized comfort benchmark in Indonesia.

**Table 5.** The average Effective Temperature in *Kobuang limo house*

| | Room | 10 - 12 December 2024 | | |
|---|---|---|---|---|
| | | Morning | Noon | Night |
| | | 07.00 - 10.00 | 12.00 - 15.00 | 19.00 - 21.00 |
| OITSIDE | Outside the House | 25.46 | 27.38 | 26.26 |
| | Under the Stage | 25.67 | 27.07 | 25.92 |
| INSIDE | Porch | 25.63 | 26.82 | 25.98 |
| | Living Room | 25.90 | 27.00 | 26.51 |
| | bed Room | 26.24 | 27.17 | 26.47 |
| | Rear Porch | 26.14 | 26.95 | 26.58 |
| | Kitchen | 26.12 | 27.12 | 26.34 |

Source: Author Analysis

From the table above, in general, the Kobuang Limo house is still in a thermal comfort condition based on the SNI 03-6572-2001 reference, except for the bedroom and kitchen. The trend of thermal comfort conditions based on effective temperature can be seen in the graph below.




**Graphics 1.** Average effective temperature trend in *Kobuang Limo House*
Source: Author Analysis

### a) Outdoor Area

ET in the outdoor area shows a comfortable warm category (25.8°C–27.1°C) in the morning and evening. However, during the day, the temperature reaches 27.38°C, slightly exceeding the comfortable limit, due to direct exposure to sunlight.

### b) Indoor Area

Most indoor spaces, such as the front porch, living room, and back porch, have ET in the optimal comfortable category (22.8°C–25.8°C) to comfortable warm (25.8°C–27.1°C). However, the bedroom and kitchen recorded the highest ET during the day, at 27.17°C and 27.12°C, respectively, indicating the need for increased ventilation or the use of heat-retaining materials to improve thermal comfort.

## 6. Monthly Effective Temperature (ET) Trends

To bridge the three-day field measurement and the year-long climate context, this study first analyzed the observed reduction of thermal parameters between outdoor and indoor environments. Table 5 below summarizes the average reduction ratio across temperature, humidity, and air velocity, which was then used as a correction factor in projecting monthly indoor thermal conditions using BMKG climate data.

Based on simulated data using monthly climate statistics and correction ratios, Effective Temperature (ET) values inside the building remain within the comfortable to slightly warm category throughout the year.

**Table 6.** Average 12-month effective temperature simulation based on BMKG data 2024

| Month | Time | Temperature | | Humadity | | Velocity | | Efective Temperature |
|---|---|---|---|---|---|---|---|---|
| | | Outdoor | Indoor | Outdoor | Indoor | Outdoor | Indoor | |
| January | Morning | 28.90 | 28.69 | 72.00 | 71.94 | 0.60 | 0.14 | 26.92 |
| | Noon | 32.70 | 32.23 | 56.00 | 51.82 | 0.60 | 0.29 | 28.07 |
| | Night | 29.00 | 28.61 | 82.00 | 81.86 | 1.20 | 0.32 | 27.08 |
| February | Morning | 29.10 | 28.89 | 68.00 | 67.94 | 0.50 | 0.11 | 26.88 |
| | Noon | 32.20 | 31.74 | 58.00 | 53.67 | 1.40 | 0.67 | 27.42 |
| | Night | 28.10 | 27.73 | 84.00 | 83.86 | 0.80 | 0.21 | 26.63 |
| March | Morning | 28.70 | 28.50 | 75.00 | 74.93 | 0.80 | 0.18 | 26.83 |
| | Noon | 32.40 | 31.94 | 61.00 | 56.45 | 1.50 | 0.72 | 27.78 |
| | Night | 27.80 | 27.43 | 88.00 | 87.85 | 0.70 | 0.19 | 26.69 |
| April | Morning | 28.40 | 28.20 | 77.00 | 76.93 | 0.60 | 0.14 | 26.84 |
| | Noon | 31.70 | 31.25 | 60.00 | 55.52 | 0.80 | 0.38 | 27.42 |
| | Night | 27.40 | 27.04 | 88.00 | 87.85 | 0.40 | 0.11 | 26.61 |
| May | Morning | 28.20 | 28.00 | 78.00 | 77.93 | 0.40 | 0.09 | 26.88 |
| | Noon | 32.20 | 31.74 | 59.00 | 54.60 | 0.90 | 0.43 | 27.72 |
| | Night | 27.90 | 27.53 | 89.00 | 88.85 | 0.80 | 0.21 | 26.77 |
| June | Morning | 27.90 | 27.70 | 77.00 | 76.93 | 0.50 | 0.11 | 26.48 |
| | Noon | 31.60 | 31.15 | 57.00 | 52.75 | 1.10 | 0.53 | 26.95 |
| | Night | 27.80 | 27.43 | 88.00 | 87.85 | 0.60 | 0.16 | 26.78 |
| July | Morning | 27.80 | 27.60 | 74.00 | 73.93 | 0.30 | 0.07 | 26.37 |
| | Noon | 32.40 | 31.94 | 59.00 | 54.60 | 0.80 | 0.38 | 27.94 |
| | Night | 28.20 | 27.82 | 84.00 | 83.86 | 0.40 | 0.11 | 27.06 |
| August | Morning | 27.90 | 27.70 | 74.00 | 73.93 | 0.70 | 0.16 | 26.13 |
| | Noon | 32.10 | 31.64 | 56.00 | 51.82 | 0.80 | 0.38 | 27.46 |
| | Night | 27.80 | 27.43 | 89.00 | 88.85 | 0.60 | 0.16 | 26.84 |
| September | Morning | 28.50 | 28.30 | 73.00 | 72.93 | 0.60 | 0.14 | 26.65 |
| | Noon | 32.40 | 31.94 | 57.00 | 52.75 | 0.90 | 0.43 | 27.74 |
| | Night | 28.10 | 27.73 | 88.00 | 87.85 | 0.70 | 0.19 | 26.97 |
| October | Morning | 28.90 | 28.69 | 71.00 | 70.94 | 0.40 | 0.09 | 27.00 |
| | Noon | 32.20 | 31.74 | 57.00 | 52.75 | 0.80 | 0.38 | 27.62 |
| | Night | 28.10 | 27.73 | 87.00 | 86.85 | 0.50 | 0.13 | 27.08 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| November | Morning | 29.10 | 28.89 | 72.00 | 71.94 | 0.60 | 0.14 | 27.10 |
| | Noon | 31.80 | 31.35 | 56.00 | 51.82 | 1.20 | 0.58 | 27.00 |
| | Night | 27.40 | 27.04 | 84.00 | 83.86 | 0.50 | 0.13 | 26.25 |
| December | Morning | 28.60 | 28.40 | 73.00 | 72.93 | 0.40 | 0.09 | 26.89 |
| | Noon | 32.80 | 32.33 | 56.00 | 51.82 | 0.60 | 0.29 | 28.15 |
| | Night | 27.90 | 27.53 | 85.00 | 84.86 | 0.50 | 0.13 | 26.77 |

Source : BMKG climate data (2024), adjusted using deviation ratios from 3-day field measurements (December 10–12, 2024) and analyzed using the Effective Temperature (ET)

**Table 7.** Average Heat Reduction Ratio between Outdoor and Indoor Conditions (10–12 Dec 2024)

| Parameter | Percentage Deviation | | |
|---|---|---|---|
| | Morning | Noon | Night |
| Temperature | 0.71% | 1.43% | 1.33% |
| Humadity | 0.09% | 7.46% | 0.17% |
| Velocity | 77.50% | 52% | 73.33% |

Source: Author

Table 6 above presents monthly averages of the building's outdoor and indoor conditions for temperature, humidity, and air velocity, obtained by applying deviation-based correction factors to the BMKG outdoor climate data. These adjusted values serve as the basis for calculating the average Effective Temperature (ET) across months. This approach ensures that the simulation considers not only the macroclimate influences but also the passive moderating effects of the building on its internal thermal environment.

The annual simulation indicates that indoor thermal conditions are generally more moderate than outdoor conditions. Indoor temperatures are consistently lower, with slightly higher humidity and reduced air velocity. Effective Temperature (ET) values range from 26.13°C to 28.15°C, mostly within the comfort range of SNI 03-6572-2001, though midday values in some months slightly exceed this threshold. The highest ET is recorded at midday in December, while the lowest occurs in the morning of August. These results show that traditional architectural elements help maintain indoor thermal comfort, although additional improvements may be needed during peak heat periods to optimize passive comfort year-round.

## Conclusion and Recommendation

### 1. Conclusion

This study examines the effectiveness of tropical architectural elements in *Kobuang Limo House* in maintaining thermal comfort, with Effective Temperature (ET) as the main benchmark based on SNI 03-6572-2001. The results of the analysis show several main findings:

a) The Contribution of Tropical Architectural Elements.

- The hip roof and *singap* ventilation contribute to air circulation, but the use of corrugated zinc roofing increases indoor temperatures during the day.
- Window openings and natural ventilation optimize airflow, although indoor wind speed remains lower than outdoor conditions.
- The raised floor effectively reduces humidity and enhances thermal comfort through passive ventilation.

b) Distribution of Effective Temperature (ET)

- The outdoor area falls into the warm, comfortable category (25.8°C–27.1°C) in the morning and night, but rises to 27.38°C during the day due to direct sunlight exposure.

- The indoor area mostly falls within the optimal to warm comfortable category (22.8°C–27.1°C), except for the bedroom and kitchen, which reach 27.17°C–27.12°C during the day, indicating the need for ventilation optimization or additional insulation.

Overall, *Kobuang Limo House* still maintains the adaptive characteristics of tropical architecture; however, some improvements are needed to enhance thermal comfort, especially during the daytime.

**2. Recommendation**

To improve the thermal performance of the *Kobuang Limo House*, key enhancements are needed in heat insulation, airflow optimization, and material efficiency. The following recommendations address these aspects to enhance thermal comfort while maintaining its traditional adaptability.

- Enhancing roof insulation is necessary to reduce heat transfer from corrugated zinc roofing.
- Optimizing cross-ventilation can improve airflow inside the house, helping to lower Effective Temperature (ET) during the day.
- Using materials with lower thermal conductivity is recommended to increase the building's thermal efficiency.

Implementing these strategies will strengthen the house's climate adaptability, ensuring sustainable thermal comfort while maintaining traditional design principles.

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