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A STUDY ON THE THERMAL COMFORT OF TRADITIONAL MALAY HOUSES IN SAMBAS CITY

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ABSTRACT

External threats such as animals, climate change, and weather conditions are commonly known factors that determine the house's primary function, which is to provide shelter and protection. The structural characteristics of the architecture of the traditional Malay House are unique in their distinctive construction techniques, design elements, functions, and decorative features. These houses, passed down through generations, have historically served as essential spaces for communal living. Thermal comfort in buildings refers to physical and physiological satisfaction, often assessed using empirical equations. This study evaluates the thermal comfort levels of traditional Malay houses in Sambas City. A descriptive quantitative approach is employed, utilizing Computational Fluid Dynamics (CFD) simulations conducted through Autodesk Inventor software to analyze indoor airflow patterns. Additionally, on-site measurements investigation is employed using an anemometer to assess wind speed, a hygrometer to determine humidity levels, and a thermometer to measure air temperature. The findings indicate that none of the case study houses meet the thermal comfort standards established by KEMENKES (Indonesian Ministry of Health) and SNI (Indonesian National Standard). As a result, residents often experience discomfort and resort to artificial ventilation at specific times to improve indoor conditions.

Keywords: Computational Fluid Dynamics (CFD), Thermal comfort, Traditional Malay House

INTRODUCTION

The house serves as a fundamental physical space for living, providing protection against external threats such as wild animals, extreme weather, and the impacts of climate change. Beyond its primary role as a shelter, it functions as a multifunctional environment for activities like relaxation, socializing, strengthening family bonds, seeking refuge, and storing valuables. Additionally, the house holds symbolic significance, often reflecting the social status of its inhabitants within a community (Azwar, 1996; Mukono, 2000, as cited in Mandaka & Wardianto, 2020). Comfort within a building is determined by several factors, including spatial, visual, acoustic, and thermal comfort (Fitriani, 1997, as cited in Andriano, 2018), with thermal comfort being particularly critical. Defined as a state of mental satisfaction with the thermal conditions of an environment (Nugroho, 2011), thermal comfort arises from the relationship between a building and its occupants, fostering feelings of comfort and pleasure (Karyono, 2010). This comfort is influenced by natural conditions that can be regulated through architectural design (Snyder, 1989, as cited in Chariyah, 2017). Orientation and opening design significantly influence architectural planning to enhance thermal comfort in wet tropical climates. Following this principle, buildings and their openings are typically oriented to avoid east and west exposures, as these directions receive direct sunlight (Adianti & Vidya, 2024). Consequently, design compromises are implemented to prevent direct solar radiation from striking the building envelope, particularly around openings. McIntyre (1980) further explains that a space achieves thermal comfort when occupants feel no need to adjust the temperature, indicating a stable and satisfactory environment. This aligns with Olgyay’s (1973) concept of the "comfort zone," where humans adapt to their surroundings, minimizing energy expenditure and maintaining thermal equilibrium.

The architectural elements of traditional Sambas Malay houses are deeply intertwined with ornaments, colors, and spatial organization, each contributing to the cultural and functional identity of the structure. Ornaments, in particular, play a significant role, as they are predominantly expressed through intricate wood carvings, which are a hallmark of traditional Malay architecture. These ornamental carvings are not merely decorative but are deeply embedded in the cultural fabric—ornamental carvings reflecting societal values, norms, beliefs, and meanings. However, in contemporary times, the use of ornaments in traditional houses has largely been reduced to a symbol of cultural identity. Ornaments often overlook their historical role in addressing climatic and thermal challenges (Hidayat, 2011). Perforated motifs characterize Malay ornamental carvings. The motifs serve a dual purpose: they allow penetration of natural light into the interior spaces while facilitating ventilation, thereby contributing to thermal comfort (Martín-Chivelet, 2025). The motifs used in traditional houses carry symbolic meanings, and their design is derived from natural and geometric patterns, including flora, fauna, and abstract designs. The ornaments also serve as key aesthetic elements, beyond their functional lighting and thermal regulation roles. The presence of ornaments enhances the visual appeal of traditional Sambas Malay buildings and preserves their cultural heritage.

According to Zain (2003), the spatial layout of traditional Malay houses in Sambas City is characterized by a distinct division of rooms, each serving specific functional and cultural purposes. The front porch, or Serambi, is a prominent architectural feature located at the front of the building and serves as the main entrance. Serambi is a multifunctional area to welcome guests and a venue for various cultural activities, including celebrations and communal gatherings. Beyond the front porch lies the middle porch, which is designed in a longitudinal pattern and functions as a transitional space between the public and private areas of the house. The middle porch in traditional Malay houses serves as a buffer zone to cover private activities in the family room and bedrooms. This space also serves as a space for male guests during cultural events such as weddings and other celebrations. The deliberate design of these porches reflects the socio-cultural values of the Malay community. The designed spaces in traditional Malay houses emphasize all community needs for hospitality, privacy, and the importance of communal activities. The adaptability to social and cultural needs is found in the spatial organization of traditional Malay architecture. Its design also highlighting the community's role in fostering interaction and preserving cultural traditions.

Thermal comfort is the most significant factor influencing all the architectural elements in the Traditional Malay House of Sambas, and it is found in the placement or design of window openings and ventilation systems. Openings and ventilations on the house facade are crucial in regulating key environmental parameters, including indoor air temperature, relative humidity, and airflow velocity within different rooms. This study employs computational fluid dynamics (CFD) analysis by simulating and analyzing airflow behavior to evaluate and optimize the ventilation performance of the building and the importance of airflow patterns in maintaining thermal comfort in the Traditional Malay House in Sambas. The simulation will provide a more in-depth understanding of thermal comfort and its contribution to the overall well-being of building occupants. The findings will enhance the knowledge of passive cooling strategies in traditional architecture, especially in Malay houses. The study also serves as a reference for sustainable design adaptations in contemporary buildings.

METHOD

This study employs the philosophy of positivism in a quantitative descriptive approach. Data was analyzed to emphasize objective and empirical validation. This methodological approach is particularly suited for examining a specific population or sample, where data collection is conducted systematically, often through random sampling techniques. Structured instruments are used to gather quantitative data to ensure the reliability and validity of the research. The primary objective of this approach is to test the hypotheses formulated during the initial research stages through statistical and quantitative analysis (Sugiyono, 2010, as cited in the STT Jaffray Lecturer Team, 2016). By utilizing this approach, the study aims to establish a clear correlation between environmental parameters and thermal comfort in traditional Sambas Malay houses.

In this research, Computational Fluid Dynamics (CFD) simulation analysis is employed with the assistance of Autodesk CFD and Inventor software tools. Direct on-site measurements are conducted to complement the software-based analysis to ensure the computational models' accuracy and validity. Autodesk CFD facilitates direct on-site measurements and analysis of output data. Data was collected through measurement activities to the environment, i.e., wind speed by an anemometer, air temperature by the thermometer, and relative humidity levels by a geometer. These empirical measurements validate the CFD simulations and ensure the study captures real-world airflow dynamics and thermal conditions with high precision. The combination of numerical simulations with field measurements will enhance the understanding of passive cooling mechanisms in vernacular architecture and contribute to sustainable design strategies in tropical climates.

The results of CFD simulations conducted on traditional Malay houses in Sambas City are presented in this discussion to explore airflow conditions. The room conditions in the CFD simulations were designed to reflect the architectural characteristics of traditional Malay houses in Sambas, particularly their numerous natural ventilation openings. Jagdale & Chaudhary (2021) resume the simulation process of Computational Fluid Dynamics (CFD) simulations involving the following stages:

- Preprocessing
  The preprocessing stage involves the preparation of the simulation model. The data on the room geometry of traditional Malay houses in Sambas was defined and served as the foundation for the entire simulation. The geometric accuracy of the room was based on field measurement data to ensure reliable simulation results as shown in Figure 1.
- Solver
  The CFD software applies mathematical equations to model fluid flow based on assumptions regarding the environmental conditions of traditional Malay houses. The building design includes four external blocks assumed to function as air intake vents and a model of the primary construction material with the wooden house structure. Airflow within the house was simulated using an assumed uniform wind velocity of 2 m/s applied on each side of the building. The airflow conditions in each room were recorded as output for further analysis of the relationships between rooms. During this stage, the researcher monitors the simulation results for accuracy and stability; repetition simulations will be performed as necessary.
- Post-processing
  The final stage involves visualizing the airflow patterns, generating graphs and charts, and extracting data. Flow visualizations aid in understanding airflow behavior, graphical outputs support interpretation and decision-making, and the data serve to validate the simulation outcomes.

This study focuses on a traditional Malay house that serves as a residential dwelling. The residential dwelling of Ibu Nilo, as a case study, is located in Dalam Kaum Village, Sambas District, Sambas Regency as illustrated in Figure 2. This house was selected as the research object due to its architectural characteristics, which align with the vernacular Malay style and provide valuable insights into passive cooling mechanisms. Measurements of thermal and environmental conditions were conducted during the day at three different times of the day—morning, afternoon, and evening—on 23 May 2022.

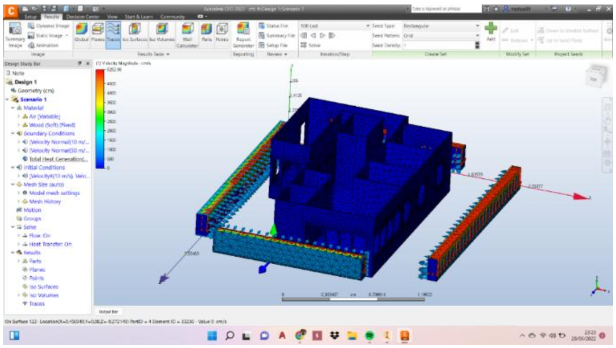

Figure 1. Computational Fluid Dynamics (CFD) simulations in 3D plan X axis
Source: Authors, (2022).

Figure 2. Research Location
Source: Google Earth, (2022).

Qualitative and quantitative approaches in data collection are conducted to analyze the object's thermal comfort conditions. First, the interview method is used to gather direct insights from the occupants regarding their experiences of indoor thermal comfort throughout the day. In interviews with occupants, researchers explore the subjective perceptions of human comfort levels to temperature, humidity, and airflow, which are crucial for evaluation. Second, observation is conducted through systematic data collection involving direct measurements of key environmental parameters, i.e., indoor temperature, relative humidity, and air velocity. Utilization of instruments to ensure precise and objective assessments of the influenced environment, i.e., thermometers, hygrometers, and anemometers. Finally, documentation plays a critical role in recording and analyzing the spatial characteristics of the house. Documentation of the object involves capturing photographs and creating 2D and 3D models and interior spaces to visualize airflow patterns and thermal variations. The study provides a comprehensive understanding of the thermal performance of traditional Malay houses, and the findings will contribute to strategies for the sustainable development of features architecture that are suited to tropical climates by integrating these methods.

RESULT AND DISCUSSION

The object of this study is located in the village of Dalam Kaum, which is home to one of the traditional Malay houses in Sambas still inhabited by residents who maintain the original architectural construction. This house serves as a residence for a family of seven, providing a practical example of how traditional structures are adapted to contemporary living needs. As a case study, this house represents a living example of traditional Malay architecture that continues to fulfill its functional role while preserving cultural heritage as shown in Figures 3 and 4.

During the measurement process, researchers observed that each room within the building featured numerous openings, such as windows and ventilation panels, facilitating significant airflow as illustrated in Figure 5. A finding of particular characteristics of traditional Sambas houses is the placement of openings in the living and family rooms to allow efficient wind circulation. It is also contributing to natural cooling and improved indoor air quality. This finding is essential for maintaining thermal comfort in tropical climates. Clearly understanding that the air accessibility in openings highlights the traditional architectural emphasis on passive ventilation strategies. The measurement data were presented in tabular and graphical formats, and visual presentations will enhance the data's interpretability and provide a comprehensive overview of the environmental conditions within the building. Therefore, it enables a deeper understanding of the relationship between architectural design and thermal performance.

Figure 3. Front Facade and Floorplan of Ibu Nilo House
Source: Authors, (2022).

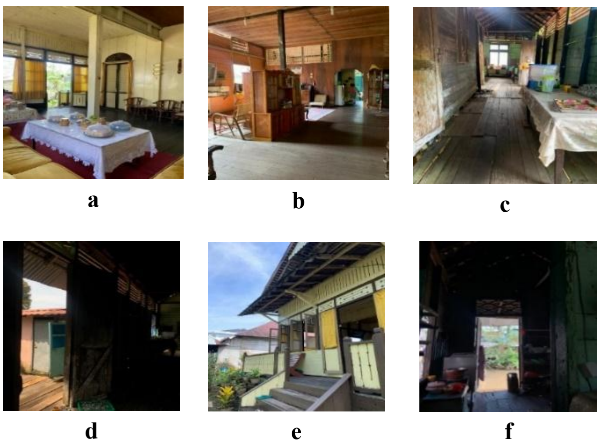

Figure 4. Interior condition of the Malay Traditional House
Source: Authors, (2022).

Notes:

a. Living room; b. Family room; c. Corridor
d. Open Platform/toilet/WC; e. Terrace; e. Kitchen

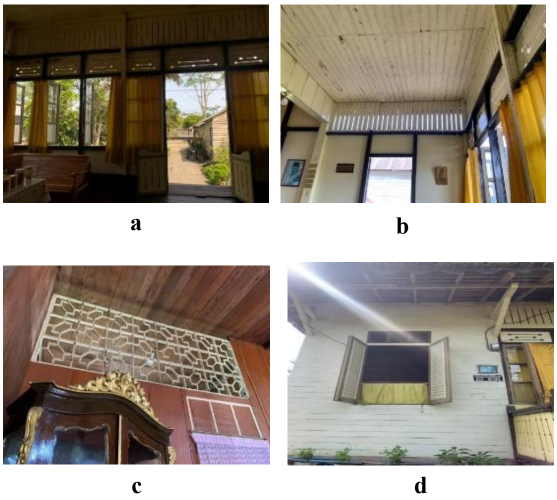

Figure 5. Openings in the inside of a Malay traditional house
Source: Authors, (2022).

Notes:
a. Door and Window in the living room
b. Ventilation in the living room
c. Ventilation in the living room
d. Window in the bedroom

Thermal Measurement

Thermal measurement throughout the day of the environment and surrounding objects gives facts on significant fluctuations in temperature. The instabilities reflect the influence of external climatic factors. In Table 1 and Figure 6, the highest temperature recorded was 37.9°C during the afternoon. This period is typically characterized by intense solar radiation and peak outdoor heat. With the lack of direct sunlight and lower outdoor temperatures, the descending temperature of 26.3°C was marked as cooler ambient conditions in the morning. These disparities findings emphasize the dynamic nature of thermal conditions in traditional buildings and highlight the importance of time-based measurements in understanding indoor environmental performance.

Table 1. Thermal Measurement Inside The House

No.	Time of measurement		
	Morning	**Noon**	**Evening**
Terrace	27,3 °C	37,9 °C	29,8 °C
Living room	27,5 °C	36,9 °C	28,2 °C
Family room	27,4 °C	36,9 °C	28,1 °C
Bedroom 1	28,9 °C	36,9 °C	28,3 °C
Bedroom 2	28,9 °C	36,9 °C	28,3 °C
Bedroom 3	28,9 °C	35,4 °C	28,3 °C
Bedroom 4	28,9 °C	35,4 °C	28,3 °C
Bedroom 5	28,9 °C	35,4 °C	28,3 °C
Bedroom 6	28,9 °C	35,4 °C	28,3 °C
Corridor	27,5 °C	37,8 °C	28,1 °C
Kitchen	27,6 °C	37,5 °C	28,1 °C
Open Platform	27,5 °C	36,9 °C	28,3 °C
Toilet/WC 1	26,3 °C	31,5 °C	27 °C
Toilet/WC 2	26,3 °C	31,5 °C	28 °C

Source: Authors, (2022).

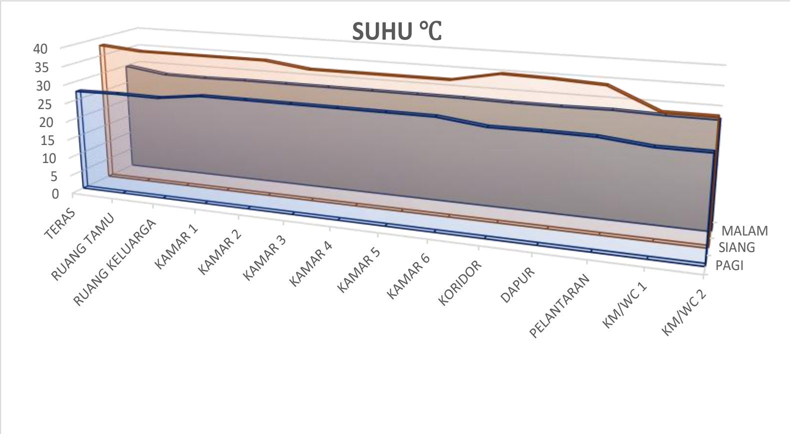

Figure 6. Thermal measurement inside the house
Source: Authors, (2022).

Air Humidity Measurement

A qualitative approach is used to capture temperature, humidity, and airflow variations throughout the day with numeric data to comprehensively understand the house's thermal performance under different climatic conditions in Sambas. The data collected revealed significant fluctuations in humidity levels over the course of the day. The humidity was recorded in Table 2 and Figure 7 as the highest score during the observation period in the morning, reaching 81.5%. This condition can be attributed to lower ambient temperatures and reduced solar radiation, leading to higher moisture retention in the air. The lowest humidity level was observed in the afternoon, in 45.5% level in the contrast. This reduction in humidity can be explained by the increase in solar radiation and air temperature during midday, which accelerates the evaporation process and reduces moisture content in the air. The variations in humidity levels play a crucial role in influencing thermal comfort to the interior of the house. A higher humidity can create a sensation of warmth and discomfort due to reduced evaporative cooling from the human body, while lower humidity may contribute to a drier indoor environment.

Table 2. Air Humidity Measurement

No.	Time of Measurement		
	Morning	Noon	Evening
Terrace	81,5 %	45,50 %	74,30 %
Living room	76 %	46,40 %	75,20 %
Family room	76,60 %	52,60 %	75,90 %
Bedroom 1	77 %	58,30 %	76,50 %
Bedroom 2	77 %	58,30 %	76,50 %
Bedroom 3	77 %	55,40 %	76,50 %
Bedroom 4	77 %	56,80 %	76,50 %
Bedroom 5	77 %	56,60 %	76,50 %
Bedroom 6	77 %	56,60 %	76,50 %
Corridor	77,80 %	55,50 %	76,50 %
Kitchen	78 %	54,40 %	75,60 %
Open Platform	78,60 %	50,10 %	75,70 %
Toilet/WC 1	79 %	58,70 %	76,80 %
Toilet/WC 2	79 %	58,70 %	76,80 %

Source: Authors, (2022).

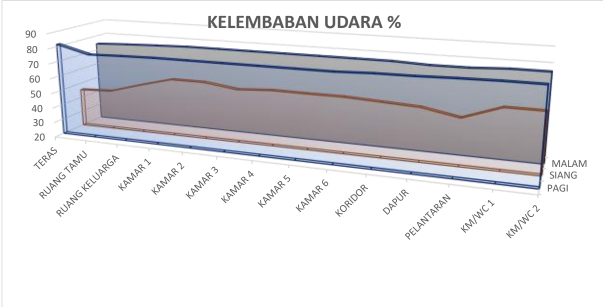

Figure 7. Air Humidity
Source: Author, (2022).

Air Velocity Measurement

Measurements of wind speed were conducted at three different times of the day—morning, afternoon, and evening—on 23 May 2022, to assess variations in natural ventilation and airflow dynamics within the traditional Malay house. The results of the wind speed records indicate the highest level during the afternoon as illustrated in Table 3 and Figure 8. The data showed it reached 2.2 mph on the terrace and open platform with favorable conditions, as semi-outdoor spaces directly exposed to external environmental conditions. In contrast, indoor spaces such as the bedroom and family room exhibited significantly lower wind speeds, ranging between 1.1 and 1.2 mph. The variation in wind speed records inside rooms can be attributed to space differences in design. An attribute in design is found as spatial configuration, openings, and cross-ventilation within the house. Notably, wind speeds were at their lowest in the morning and evening at zero mph. It suggests minimal or no natural airflow during these periods. Furthermore, certain rooms in the house remained unaffected by wind movement even during the afternoon, indicating potential areas of stagnant air that could impact overall thermal comfort.

Simulation of Airflow Patterns Using CFD

The simulations were performed using Autodesk Inventor for 3D modeling and Autodesk CFD to analyze airflow patterns within the building. The simulated area represents a typical living environment, accommodating five individuals engaged in medium-level activities. The design of room conditions reflects the traditional architectural features of Malay houses in Sambas. Commonly found as main features in traditional houses of Sambas, each room will have considerable openings for natural ventilation. Particularly, the house's model incorporates approximately 24 windows and 4 main doors, all strategically connected to the external environment to facilitate airflow. As noted in this study, the simulation assumes the absence of artificial cooling systems, emphasizing the reliance on passive design strategies to maintain thermal comfort. These simulations provide valuable local wisdom about the traditional Malay house and the significance of ventilation systems in regulating indoor air quality and thermal conditions. The design also highlights the adaptability of traditional Malay houses to the tropical climates in Sambas.
From the analysis of the air distribution and temperature patterns on the X plane, it is observed that the outdoor temperature is relatively high, ranging from approximately 35°C. This elevated temperature can be attributed to the building's location directly facing the Sambas River. As in observation, the building's facade experiences direct sunlight

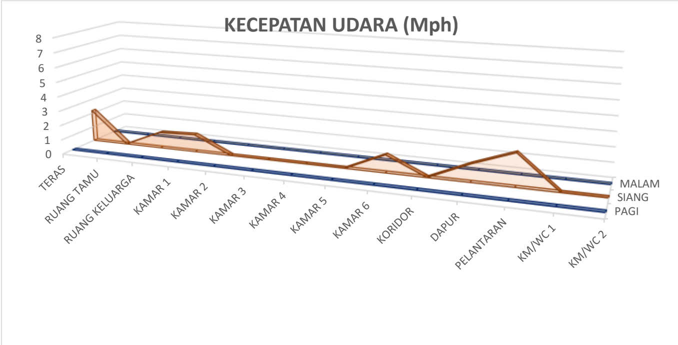

Figure 8. Air Velocity
Source: Authors, (2022).

reflection, contributing to the heat buildup on the exterior surfaces throughout the day. Inside the rooms, temperature conditions vary between 27°C and 35°C as illustrated in Table 4 and Figure 9, reflecting the dynamic nature of the internal environment. The difference in air pressure from exterior to interior, coupled with the disparity in environmental temperatures, leads to air movement. within the building. Air movement is crucial in maintaining thermal comfort in the house interior. It is further influenced by the prevailing wind speed, demonstrating the interplay between external climatic factors and internal ventilation dynamics.

Table 3. Air Velocity Measurement

No.	Time of Measurement		
	Morning	**Noon**	**Evening**
Terrace	0,0 Mph	2,2 Mph	0,0 Mph
Living room	0,0 Mph	0,0 Mph	0,0 Mph
Family room	0,0 Mph	1,1 Mph	0,0 Mph
Bedroom 1	0,0 Mph	1,2 Mph	0,0 Mph
Bedroom 2	0,0 Mph	0,0 Mph	0,0 Mph
Bedroom 3	0,0 Mph	0,0 Mph	0,0 Mph
Bedroom 4	0,0 Mph	0,0 Mph	0,0 Mph
Bedroom 5	0,0 Mph	0,0 Mph	0,0 Mph
Bedroom 6	0,0 Mph	1,2 Mph	0,0 Mph
Corridor	0,0 Mph	0,0 Mph	0,0 Mph
Kitchen	0,0 Mph	1,2 Mph	0,0 Mph
Open platform	0,0 Mph	2,2 Mph	0,0 Mph
Toilet/WC 1	0,0 Mph	0,0 Mph	0,0 Mph
Toilet/WC 2	0,0 Mph	0,0 Mph	0,0 Mph

Source: Authors, (2022).

Table 4. Average of Measurement

Type of measurement	Time of measurement		
	Pagi	**Siang**	**Malam**
Temperature	27 °C	35 °C	28 °C
Air Humidity	77 %	54 %	76 %
Air Velocity	0 Mph	0,65 Mph	0 Mph

Source:Authors, (2022).

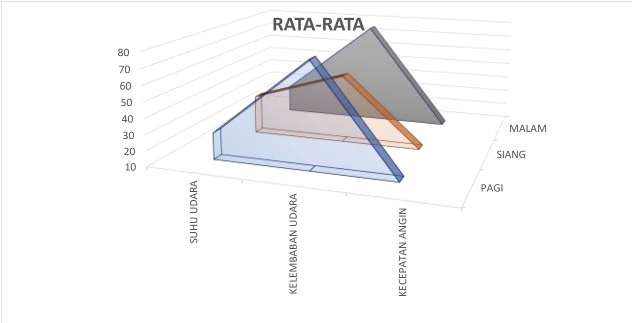

Figure 9. Average Result of Measurement
Source: Authors, (2022).

As illustrated in the Figure 10, the airflow within the building is primarily directed through openings such as doors, ventilation gaps, and windows. These openings serve as critical pathways for air to enter and circulate throughout the space, facilitating natural ventilation. However, particular areas within the room are not exposed to airflow due to their distance from these openings. These zones experience stagnant air, which can negatively impact thermal comfort. Air movement within the building occurs due to the temperature differential between the interior and exterior environments. This temperature gradient causes the air to flow vertically and horizontally, with warm air rising and cooler air filling the lower regions of the space. Vertical and horizontal air movements create a dynamic flow pattern that helps regulate the indoor climate. Understanding airflow behavior concerning temperature variations is essential for optimizing natural ventilation strategies, as it can significantly influence the overall thermal comfort of the building's occupants. Through this analysis, the study aims to identify key factors that affect airflow distribution and suggest improvements to enhance natural cooling and ventilation within traditional Malay houses.

The results of the Computational Fluid Dynamics (CFD) in Figure 11 simulation reveal that rooms with more openings experience higher airflow levels. Due to their numerous ventilation points, the living room and family room allow for more effective air circulation and cooling. In contrast, many rooms in the house are in failing condition within a relatively hot temperature range, with the average room temperature reaching approximately 35°C. The indoor environment conditions that influenced the temperature escalation can be attributed to the building's design and the climatic conditions. According to Monica et al. (2022), the airflow pattern in rooms with linear configurations facilitates the efficient movement of air with minimal resistance, as it enables the flow to enter through the inlet openings and exit through the outlet openings. This streamlined airflow configuration effectively ensures that air moves swiftly through the room, improving ventilation and thermal comfort. These findings highlight the critical role of enhancing natural ventilation and controlling indoor temperatures with room layout and the placement of openings. By optimizing the distribution of openings, it is possible to significantly improve the airflow and thermal conditions within the building, contributing to better occupant comfort and energy efficiency.

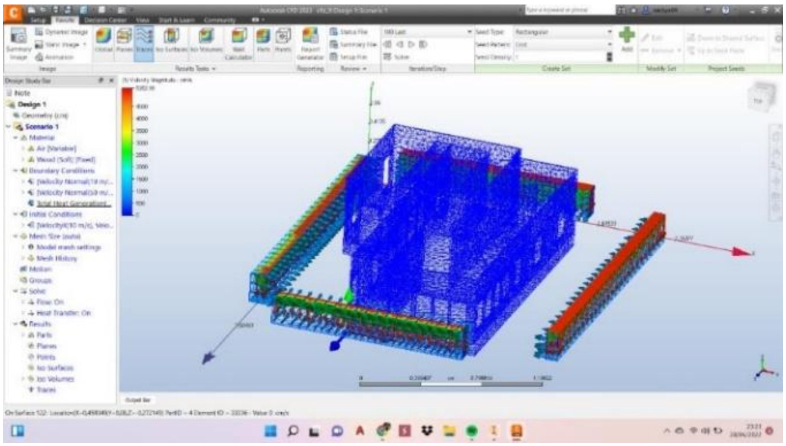

Figure 10. Airflow in Simulation
Source: Authors, (2022).

Findings on the Thermal Conditions inside the house

Thermal measurements in traditional Malay houses were conducted at three different times of the day—morning, afternoon, and evening—on the same day to analyze temperature variations and their impact on indoor comfort. In the morning, temperature measurements indicated an average indoor temperature of 27°C, with minimal variation between different rooms. Areas with ventilation openings and fewer furnishings-maintained temperatures between 26°C and 27°C, whereas the bedroom area exhibited slightly higher temperatures, averaging around 28°C. According to the thermal comfort standards outlined in SNI T-14-1993-037, the morning temperature falls within the "Warm Comfortable" category, as the effective temperature ranges between 25.8°C and 27.2°C.

During the afternoon, a significant increase in temperature was observed, particularly in the transition from the terrace to the interior of the building. The temperature in the living spaces peaked at approximately 35°C, marking a drastic change from the morning conditions. Additionally, there were substantial differences in humidity levels between indoor and outdoor spaces, as noted in previous studies (Hermawan et al., 2018). According to the thermal comfort classification in SNI T-14-1993-037, the daytime temperature exceeds 27°C, placing it in the "Uncomfortable Hot" category.

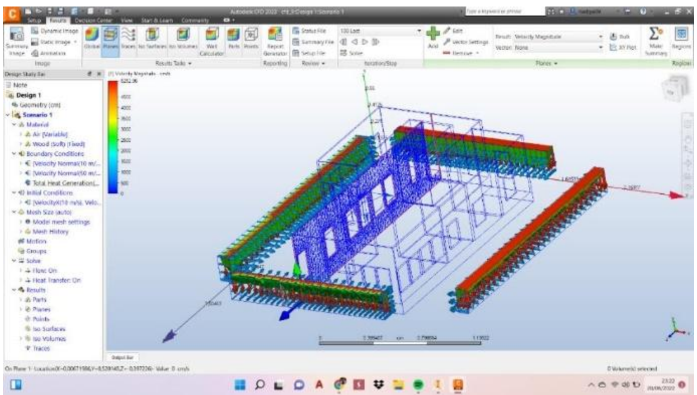

Figure 11. Final Simulation
Source: Authors, (2022).

The final measurement, taken in the evening, revealed a temperature level higher than that recorded in the morning. The average nighttime temperature was approximately 28°C, indicating sustained heat retention within the building. Based on the thermal comfort standards set by SNI T-14-1993-037, this temperature also falls into the "Uncomfortable" category, as it exceeds the 27°C threshold. These findings highlight the thermal challenges faced by traditional Malay houses, particularly in maintaining indoor comfort during the hotter periods of the day. The data suggest that improving natural ventilation strategies and optimizing passive cooling techniques could enhance the thermal performance of these structures, contributing to greater indoor comfort for occupants.

Findings on Air Humidity Conditions inside the house

Humidity measurements in the interior conducted in the morning revealed an average humidity level of approximately 77%, with minimal variation observed between rooms. The living room exhibited a slightly lower humidity level of 76%. According to SNI 03-6572-2001, the recommended relative humidity for tropical regions ranges between 40% and 50%. The data indicates that the morning humidity levels exceed the standard threshold. Edar and Wahyuni (2021) note that high humidity levels significantly influence air temperature fluctuations, underlining the importance of maintaining optimal humidity for thermal comfort.

During the afternoon, humidity measurements showed a notable decrease compared to the morning, with an average value of around 54%. Despite this reduction, the afternoon humidity levels still did not meet the standard specified by SNI 03-6572-2001.

In the evening, weather conditions changed dramatically, with rainfall occurring during the measurement period. This resulted in a sharp increase in humidity, with an average level of 76%, and far exceeding the standard recommended by SNI. These findings highlight the significant impact of weather conditions on indoor humidity levels and emphasize the challenges of maintaining optimal humidity in tropical climates.

Findings on Air Velocity Conditions inside the house

The Regulation of the Minister of Health of the Republic of Indonesia Number 1077/MENKES/PER/V/2011 stipulates that comfortable indoor airspeed ranges between 20 and 60 feet per minute (fpm), equivalent to approximately 0.6 to 2 miles per hour. Airspeed measurements conducted in the morning under consistent conditions across all rooms align with this standard. The direction and velocity of airflow significantly influence indoor air quality, as indicated by variations in the volume of circulated air, the ventilation coefficient, and the air's capacity to absorb heat (Dewi, 2012). During the daytime, airspeed measurements reveal higher values compared to those recorded in the morning, likely due to increased temperature differentials and external environmental influences. Conversely, nighttime measurements show a notable decrease, with the average airspeed dropping to 0.0 miles per hour, indicating stagnant air conditions. Based on the findings discussed above, a summary of the results is presented in Table 5.

A comparison of thermal comfort measurements—specifically temperature, humidity, and air velocity—with the standards set by KEMENKES and SNI indicates that none of the three parameters meet the established thermal comfort criteria. As a result, occupants often experience discomfort and may require artificial ventilation at certain times to maintain a more suitable indoor environment. While the presence of relatively large openings facilitates the circulation of outdoor air into the building, CFD simulations reveal that solar radiation during the day can become trapped inside. This is primarily due to the low outdoor wind pressure and velocity, which range only from approximately 0.65 to 2 mph, limiting the effectiveness of natural ventilation.

According to Zain and Oktafiansyah (2023), temperature variations within traditional Malay houses show a consistent trend, where areas closer to exterior openings tend to have lower temperatures, whereas interior spaces farther from these openings experience higher temperatures. The architectural design of traditional Malay houses, which incorporates strategic openings and lightweight construction materials, aims to mitigate indoor temperature increases by promoting airflow and heat dissipation. However, despite these design strategies, external environmental factors, such as wind speed and solar radiation, play a significant role in influencing indoor thermal comfort.

Tabel 5. Evaluation of Thermal Condition Inside The Traditional House

Variable of measurement	Standard	Thermal condition measurement			notes
		morning	noon	evening	
Temperature	Standard of thermal comfort zone in Indonesia (effective temperature): SNI T-14-1993-037 -cold un-comfort (TE)= < 20,5 °C cool- comfort (TE)= 20,5 °C-22,8°C comfort Optimal (TE)= 22,8 °C-25,8°C -warm- comfort (TE)= 25,8°C-27,2°C -hot un-comfort (TE)= >27,2°C	27 °C	35 °C	28 °C	Failed to reach the comfort temperature standard, meeting only the 'Warm Comfortable' category in the morning
Air Humidity	SNI 03-6572-2001 relative air humidity for tropical area 40%-50%.	77 %	54 %	75 %	Air humidity levels do not comply with comfort standards
Air Velocity	four condition level on air velocity (MENKES): -<0,25 m/s is comfort, Air movement is not detectable -0,25-0,5 m/s is comfort, Air movement is detectable -1,0-1,5 m/s The airflow is perceived as light but can become uncomfortable	0 Mph	0,65 Mph	0 Mph	Failed to meet the overall standard; however, it met the airspeed comfort standard during the day

Source: Authors, (2022).

CONCLUSION

The thermal comfort conditions of traditional Malay houses in Sambas align with the factors that affect human physical health, particularly the comfort zone. The comfort zone is influenced by many factors, such as radiant air temperature, water vapor humidity, and air movement. All the factors collectively create a comfortable environment when they fall within the appropriate range. However, during observations of air temperature throughout the morning, afternoon, and evening, the recorded conditions do not meet the thermal comfort standards outlined in SNI T-14-1993-037. Comfortable air temperature conditions were only observed in the morning, where the temperature of 27°C was classified as "Comfortable Warm." External factors, such as wind speed and solar radiation, significantly influence the indoor thermal comfort of traditional Malay houses. Consequently, inhabitants experience discomfort during certain times of the day and may rely on artificial wind harvest to mitigate the conditions.

Traditional Malay houses in Sambas feature distinctive architectural elements, including numerous openings, ample ventilation, and high ceilings. However, these design features do not always ensure thermal comfort that aligns with established standards. The number and placement of openings also contribute to inconsistent circulation and variations in air temperature and humidity, which are further influenced by external solar radiation. Thermal conditions for air humidity exceeded the comfort standards, with relative humidity values ranging from 54% to 77%. According to SNI 03-6572-2001, the recommended relative humidity for tropical regions should be between 40% and 50%.

Furthermore, thermal conditions for airspeed were inadequate, with airspeed values only reaching acceptable levels during the day, ranging from 0 to 0.65 mph. In conclusion, the architectural design of traditional Malay houses in Sambas incorporates features conducive to ventilation. Due to the current thermal conditions in Sambas, the house design still does not supply optimal comfort for occupants' activities in the interior.

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