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Analysis of Thermal Performance in The Prayer Hall of The Nurul Yaqin Mosque in Palu City

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Abstract
Mosques, as places of worship in tropical climates, face challenges in maintaining thermal comfort due to high ambient temperatures and humidity. This study aims to evaluate the thermal performance of mosque prayer halls by analyzing variations in temperature, humidity, and wind movement, as well as identifying the contributions of ventilation systems and landscape elements to indoor comfort. The methodology involved continuous measurements of temperature, humidity, and wind speed over eight days using data loggers and a weather station, as well as correlation analysis and interpretation of the daily patterns in the data. The main results show that cross-ventilation (top-to-bottom), vegetation, and water features play a significant role in stabilizing the temperature and humidity of the prayer hall, especially when winds predominantly come from the west and south. During the eight-day observation period, the maximum temperature inside the prayer hall was recorded at 31.8°C, while the minimum temperature was 24.2°C. The study's conclusions affirm that passive design strategies, ventilation management, landscape optimization, and routine monitoring are crucial for ensuring thermal comfort in mosques in tropical climates.

Keywords: Thermal Performance; Cross-Ventilation; Tropical Climate; Thermal Comfort

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I. INTRODUCTION

Thermal comfort is one of the key aspects in building design and management, particularly in spaces used for communal activities such as mosques. In tropical regions like the city of Palu, the main challenges in achieving thermal comfort are high air temperatures, relatively high humidity, and wind patterns that do not always support optimal natural ventilation. These conditions often affect the quality of worship and the comfort level of worshippers in the prayer hall, making it essential to conduct a comprehensive thermal performance analysis.

According to the Indonesian National Standard SNI 03-6572-2001, the primary parameters influencing thermal comfort include air temperature, relative humidity, and air movement within the space. This standard also establishes the ideal comfort zone for public spaces in tropical regions, with the optimal indoor temperature range set at 25°C ± 1°C and relative humidity around 55% ± 10%. Implementation of this standard is crucial, given that ventilation design and indoor air management in mosques must maintain ideal thermal conditions to enhance the quality of worship and improve energy efficiency.

Previous studies have shown that thermal conditions inside mosques are significantly influenced by external factors, such as outdoor air temperature, outdoor relative humidity, and wind movement and speed. Research (Iqbal, Atthaillah, Safyan, et al., 2024) confirms a strong correlation between outdoor humidity and temperature and indoor conditions, as well as the importance of natural ventilation in regulating air exchange. Airflow through window openings has been shown to influence indoor temperature; however, its effectiveness depends heavily on the design, size, and orientation of the available openings. Therefore, optimizing cross-ventilation and adjusting window openings are key strategies for controlling temperature and humidity in tropical mosques.

On the other hand, thermal studies of mosques have also identified several challenges in achieving a comfort zone, particularly in buildings with suboptimal natural ventilation. As reported by Chandra & Azizah (2023) in a case study of the Fadlurrahman Mosque at Muhammadiyah University of Surakarta, the average temperature in the prayer hall tends to exceed the comfort range, even when outdoor wind speeds are relatively high. Limitations in the number and placement of openings, as well as a lack of effective cross-ventilation, result in suboptimal air circulation, causing indoor temperature and humidity to remain high. These conditions underscore the importance of natural ventilation systems that adapt to the local climate, as well as building designs that respond to wind direction and speed.

Based on this background, this study aims to analyze the thermal performance of the prayer hall at the Nurul Yaqin Mosque in Palu City by measuring temperature, humidity, and the effects of wind movement and speed. The results of this analysis are expected to provide an empirical picture of actual thermal conditions and serve as a basis for recommendations regarding the design and management of thermal comfort in mosques, particularly in tropical regions.

II. THEORETICAL BASIS

1. Theory of Building Thermal Performance

Building thermal performance is the study of a space or building's ability to maintain comfortable thermal conditions for its occupants, both passively and actively. The primary parameters considered include air temperature, relative humidity, and indoor air movement. According to SNI 03-6572-2001, thermal comfort is significantly influenced by the balance of these three factors; therefore, the design of ventilation systems, insulation, and openings is crucial for controlling the thermal environment inside a building. Other studies also confirm that thermal performance is determined not only by the building's physical characteristics but also by external factors such as the microclimate, building orientation, materials, and occupant activities (Ngurah Aritama & Pradnya Paramitha, 2023).

The use of low-conductivity materials, reflective roof designs, and vegetation around the building has proven effective in lowering indoor temperatures and improving thermal comfort, as noted by (Zuraihan et al., 2023). Furthermore, the design characteristics of both traditional and modern homes indicate that environmental adaptation strategies have long been an integral part of efforts to maintain thermal stability within buildings (Ngurah Aritama & Pradnya Paramitha, 2023).

2. Temperature and Thermal Comfort in Buildings

Air temperature is the dominant variable in determining the level of thermal comfort within a space. According to SNI 03-6572-2001, the thermal comfort zone for tropical regions is 25°C ± 1°C, with tolerance limits under certain conditions. Several studies indicate that indoor temperatures above the optimal range can lead to reduced comfort, concentration, and productivity among building occupants.

Research (Nasrul et al., 2024) on lecture halls and (Sekar Larasati & Setyowati, 2023) on high school classrooms shows that indoor temperatures often exceed the comfort range, necessitating design measures such as increased ventilation, air conditioning, or natural shading to lower the temperature. Studies on mosques have also found that temperatures inside prayer halls tend to be high, especially during times of mass use (Luthfiyah Zahran et al., 2023) and (Alauddin & Mustamin, 2020).

Air temperatures in mosques that exceed standards cause worshippers to feel hot and stuffy, thereby reducing comfort during worship (Syamsiyah & Izzati, 2021). In studies of public spaces such as MRT stations, the comfortable temperature for users may be higher than the national standard, but ventilation strategies and microclimate management are still required to achieve optimal comfort (Delyuzir et al., 2023).

3. The Role of Humidity in Thermal Comfort

Relative humidity is the second determining factor in the thermal comfort system. SNI 03-6572-2001 recommends a relative humidity of 55% ± 10% for tropical public spaces, with a tolerance of up to 60% in high-capacity spaces. Humidity levels that are too high or too low can cause thermal discomfort, even at air temperatures that fall within the comfortable range.

A study (Iqbal, Atthaillah, Safyan, et al., 2024) found a strong correlation between outdoor humidity and indoor temperature. High humidity increases the sensation of heat, while low humidity carries the risk of causing dry skin and irritation. Research (Chandra & Azizah, 2023) and (Prabowo Sulistiawan et al., 2020) indicates that humidity levels inside mosques often exceed optimal limits, particularly at certain times such as dawn or when congregant density increases, thereby reducing congregants' comfort.

Studies in mosques and other public spaces also report that an imbalance between temperature and humidity can exacerbate thermal discomfort, particularly in areas with naturally high humidity levels, such as coastal regions or cities with tropical climates (Asyrafi & Indrawati, 2022) and (Wulandari1 & Zulfikri, 2024).

4. The Effect of Wind on Temperature and Humidity

Air movement, or wind speed, plays a crucial role in the distribution of heat and humidity within buildings. SNI 03-6572-2001 recommends that indoor wind speeds not exceed 0.25 m/second to avoid discomfort caused by excessive airflow. Wind can help lower air temperature, increase sweat evaporation, and improve indoor air quality.

(Iqbal, Atthaillah, Nayan, et al., 2024) confirm that airflow through ventilation systems and window openings significantly affects indoor temperature and humidity. Studies in tropical mosques and cafes also demonstrate that cross-ventilation is far more effective in maintaining stable temperature and humidity levels compared to single-sided ventilation (Wulandari1 & Zulfikri, 2024). However, many studies have found that even with numerous openings, indoor air velocity can be very low if the ventilation design is suboptimal, making the use of fans or mechanical ventilation still necessary (Asyrafi & Indrawati, 2022).

In mosques with minimal openings or suboptimal air circulation patterns, wind speeds tend to be low, causing temperatures to remain high and reducing worshippers' comfort (Syamsiyah & Izzati, 2021). Thus, ventilation designs that account for the direction and patterns of natural wind are essential for buildings in tropical climates.

5. Previous Studies on Thermal Performance

Various studies on the thermal performance of mosques in Indonesia indicate that the majority of prayer spaces still face challenges related to high temperatures and humidity, as well as limited air movement.

A study at the Fadlurrahman UMS Mosque by Chandra & Azizah (2023) found that the average temperature inside the prayer hall was outside the comfort range, even when outdoor wind speeds were relatively high, due to insufficient natural ventilation. Research at the Pasundan 1 High School Mosque in Bandung (Luthfiyah Zahran et al., 2023) and the Lautze 2 Mosque in Bandung (Prabowo Sulistiawan et al., 2020) also found uncomfortable thermal conditions when the spaces were full of activity, primarily due to suboptimal air circulation and high humidity.

A study (Syamsiyah & Izzati, 2021) highlights the importance of adjusting window design and adding vegetation to improve natural airflow. Meanwhile, a comparative study by (Asyrafi & Indrawati, 2022) at the Baiturrahim Mosque in Kuala Tungkal showed that despite having numerous openings, indoor wind speeds remained low and did not meet comfort standards, making the use of mechanical ventilation still necessary.

Similar results were also found in other studies of tropical public spaces such as MRT stations (Delyuzir et al., 2023), museums (Ikramina et al., 2020), cafes (Wulandari1 & Zulfikri, 2024), and even classrooms (Sekar Larasati & Setyowati, 2023) and (Nasrul et al., 2024). These conditions underscore the importance of designs responsive to the tropical climate to maintain thermal comfort in public spaces.

6. Thermal Comfort Standards and Criteria

Thermal comfort criteria in Indonesia generally refer to SNI 03-6572-2001. SNI 03-6572-2001 specifies the optimal ranges for temperature, humidity, and wind speed in public spaces in tropical regions, namely an indoor temperature of approximately 25°C ± 1°C, humidity of 55% ± 10%, and a wind speed not exceeding 0.25 m/s. This standard also recommends the implementation of cross-ventilation systems, the use of well-insulated materials, and the adjustment of opening designs to achieve a thermal comfort zone for building occupants.

Furthermore, several studies emphasize the importance of adapting these standards based on local microclimate conditions, occupant activities, and space density (Ngurah Aritama & Pradnya Paramitha, 2023). With consistent implementation of these standards, it is hoped that public buildings—particularly mosques—can provide optimal thermal comfort for worshippers.

III. RESEARCH METHODS

1. Research Type and Approach

This study employs a descriptive quantitative approach using survey methods and direct measurements to obtain an overview of the thermal performance of the prayer hall at the Nurul Yaqin Mosque in Palu. Data were collected empirically using instruments to measure temperature, humidity, and wind movement and speed, then statistically analyzed and compared with thermal comfort standards. This approach allows for an objective and in-depth evaluation of thermal conditions, appropriate for the context of a building in a tropical climate.

2. Research Location and Timeframe

This study was conducted in the main prayer hall of the Nurul Yaqin Mosque in Palu City, located in Palu City, Central Sulawesi Province, Indonesia. Palu City is situated on the island of Sulawesi, specifically in Central Sulawesi Province, Indonesia (Figure 1). Astronomically, Palu City is located at coordinates 0°54' S and 119°50' E, near the equator. This location results in nearly uniform daylight hours throughout the year, with consistent sunlight exposure. Measurements were taken for 8 consecutive days, 24 hours per day, beginning on Thursday, May 29, 2025, at 10:00 a.m. WITA and ending on Thursday, June 5, 2025, at 5:00 p.m. WITA, with the aim of capturing variations in thermal patterns during the morning, afternoon, and night.

Figure 1: The City of Palu on the Map of Indonesia
Source: Map of Indonesia

The geographical and astronomical location of Palu, which lies close to the equator, gives the region a tropical climate characterized by generally high air temperatures, relatively high humidity, and significant solar radiation throughout the year. Consistent exposure to sunlight contributes to high outdoor air temperatures, which in turn affect indoor temperatures, particularly in spaces used by large numbers of people, such as mosques.

These conditions present a unique challenge in achieving thermal comfort, as buildings in Palu must be able to mitigate heat transfer from the exterior into the interior through walls, roofs, and openings. In addition, high humidity also affects the effectiveness of natural cooling and user comfort. Therefore, this study is crucial for understanding how the climatic characteristics of Palu City influence the thermal performance of prayer halls, as well as for formulating appropriate management strategies to support the comfort of worshippers in a tropical climate.

The Nurul Yaqin Mosque is strategically located in Palu City, making it an ideal subject for analyzing the thermal performance of prayer spaces in tropical regions. This study utilizes local data, including air temperature, humidity, and outdoor wind patterns, which were measured directly on-site. The use of this measurement data ensures that the thermal performance analysis is highly relevant to actual conditions and can provide an accurate picture of the challenges and potential solutions for thermal comfort in the mosque.

The following are the location points on the map of Palu City and documentation of the Nurul Yaqin Mosque that illustrate the surrounding area (Figure 2):

Figure 2: Location and Setting of the Nurul Yaqin Mosque in Palu City
Source: Field Data

By understanding the geographic, astronomical, and climatic characteristics of this location, the study can integrate environmental factors into its thermal performance analysis, thereby yielding more comprehensive and relevant findings.

3. Research Instruments and Measurement Procedures

This study relied on two main types of instruments to accurately obtain thermal performance data: the Ecowitt Weather Station for the outdoor environment and a data logger for the interior of the prayer hall. The procedures for using each instrument are described as follows:

1). Ecowitt Weather Station

The Ecowitt Weather Station (Figure 3) is used to measure air temperature, relative humidity, and wind direction and speed in the area outside the mosque. Before measurements begin, the device is first calibrated according to the manufacturer's standards to ensure data accuracy. After calibration, the Ecowitt Weather Station is placed at a strategic location outside the building, in an open area free from obstacles such as trees, high walls, or other structures that could interfere with data collection. This placement is intended to allow the device to accurately record the microclimate conditions around the mosque.

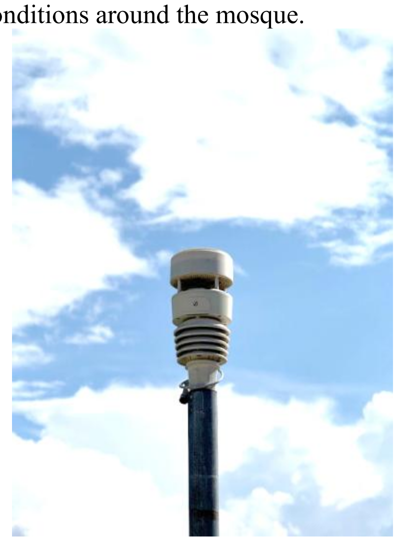

Figure 3: Ecowitt Weather Station
Source: Field Data

For eight consecutive days, the Ecowitt Weather Station operated automatically and continuously for a full 24 hours each day. Data on air temperature, humidity, and wind speed and direction were recorded periodically at 5-minute intervals. This automatically recorded digital data was then downloaded and stored electronically for further analysis. In addition, daily checks were conducted to ensure the equipment continued to function properly throughout the data collection period.

2). Data Loggers

Six data loggers were installed inside the mosque's prayer hall to measure air temperature and relative humidity at predetermined points: three on the west side, and one each on the south, east, and north sides of the room. The devices were mounted on the mosque's columns along the sides of the building (Figure 4). Prior to installation, each data logger was calibrated to ensure the accuracy of the readings. Once installed, the devices automatically recorded temperature and humidity for eight consecutive days without requiring manual intervention. Data is collected at 5-minute intervals, allowing for detailed monitoring of daily thermal fluctuation patterns and variations between measurement points. At the end of the measurement period, the digital data is downloaded and compiled for further analysis. The devices are also inspected periodically to ensure that all units are functioning optimally until data collection is complete.

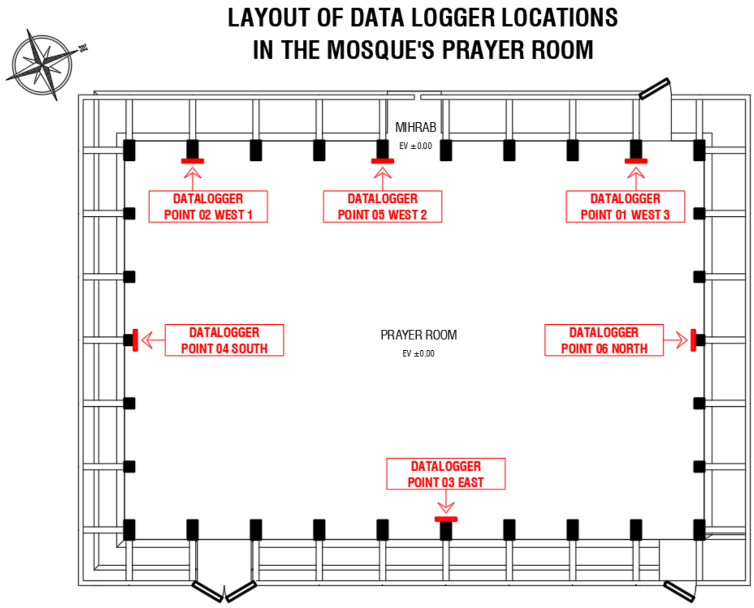

Figure 4: Data Logger Installation Locations in the Mosque Prayer Hall
Source: Field Data

3). Data Collection Techniques

Data for this study were collected through automatic and continuous measurements using the instruments installed as described in section 3.3. above. Each data logger installed at six points within the prayer room recorded air temperature and relative humidity at 5-minute intervals. Placing the devices at three strategic points on the west side and one each on the south, east, and north sides allowed for a comprehensive picture of the thermal distribution throughout the prayer hall.

Meanwhile, the Ecowitt Weather Station, placed outside the building, automatically recorded air temperature, relative humidity, and wind speed and direction at 5-minute intervals during the observation period. Placing this device in an open, unobstructed area ensures that the data obtained accurately represents the microclimate conditions around the mosque.

All measurement data from the data logger and the Ecowitt Weather Station were digitally recorded, then downloaded and archived to facilitate further analysis. This automated data collection was also supported by periodic equipment checks to maintain the quality and consistency of the research results.

4). Data Analysis Techniques

The measured data on air temperature, relative humidity, and wind speed obtained from the data logger and the Ecowitt Weather Station were analyzed using quantitative-descriptive methods to identify and evaluate thermal performance patterns in the prayer hall of the Nurul Yaqin Mosque. The analysis was conducted using the following steps:

a. Data Tabulation and Validation

All digitally recorded data were downloaded, compiled, and tabulated using data processing software such as Microsoft Excel or other statistical software. Prior to analysis, validation was performed to check data consistency and eliminate invalid data resulting from instrument malfunctions or recording anomalies.

b. Descriptive Statistics

Descriptive statistical analysis was used to determine the mean, minimum, and maximum values of temperature, humidity, and wind speed. The analysis was performed for each measurement point and compared across points to identify variations in thermal distribution within the prayer hall.

c. Graphical Visualization of Daily Patterns

Temperature, humidity, and wind speed data were plotted as time series graphs to observe daily fluctuation patterns and temporal variations over the eight-day observation period. This visualization helps identify trends where thermal performance deviates from the comfort range.

d. Spatial and Temporal Comparison Analysis

A comparison was conducted between data from each point within the prayer room (e.g., west, south, east, and north sides) and outdoor data to assess the influence of room orientation, solar exposure, and wind direction on thermal conditions.

e. Correlation Analysis

To evaluate the relationship between outdoor wind speed and indoor temperature and humidity, a simple correlation analysis was used to determine the extent to which wind movement affects the thermal conditions of the prayer room.

f. Comparison with Thermal Comfort Standards

All measurement results were compared with the applicable thermal comfort standards in accordance with SNI 03-6572-2001 to determine whether the prayer room meets the temperature and humidity comfort requirements for worshippers.

g. Interpretation of Results and Synthesis of Findings

After the quantitative analysis was conducted, the results were interpreted narratively and compared with the findings of previous studies. This synthesis of findings will serve as the basis for formulating recommendations regarding the design or management of thermal comfort in mosques.

Through a structured data analysis process based on automated measurement data and statistical processing, this study is expected to provide an accurate empirical picture of the thermal performance of the prayer hall at the Nurul Yaqin Mosque in Palu.

IV. RESULT AND DISCUSSION

1. Analysis of Daily Temperature Patterns in the Prayer Hall

Temperature observations in the prayer hall of the Nurul Yaqin Mosque were conducted over eight days (May 29–June 5, 2025) at six measurement points (West 1, West 2, West 3, South, East, North). In general, the daily pattern was consistent: temperatures rose gradually starting in the morning, peaked in the afternoon–evening, and then declined slowly after sunset. The western points consistently remained the hottest areas due to direct solar radiation in the afternoon, while the eastern, southern, and northern sides tended to be more stable.

Indoor temperatures are always lower than outdoor temperatures at the midday peak, but at night the decline is slower due to heat retention within the building structure. Friday (May 30) recorded the highest average temperature due to a combination of high outdoor temperatures and internal heat load from the activities of Friday prayer congregants. In contrast, Sunday (June 1) showed the lowest and most stable temperatures, presumably due to cloud cover and low activity levels. A quantitative summary by day is presented in Table 1.

Table 1: Summary of daily temperatures in the prayer room and their correlation with outdoor temperatures.
Source: Field Data

Hari / Tanggal	Suhu Maks Dalam (°C)	Suhu Min Dalam (°C)	Suhu Rata² (°C)	Suhu Maks Luar (°C)	R²	Slope
Kamis, 29 Mei	30,6–31,6	25,0–26,9	27,0–29,0	31,6–32,4	0,75–0,86	0,40–0,60
Jumat, 30 Mei	31,2–31,7	24,8–26,4	27,5–29,1	32,9–33,4	0,74–0,85	0,53–0,65
Sabtu, 31 Mei	29,7–30,6	24,8–25,8	27,0–28,4	30,2–31,0	0,65–0,79	0,35–0,65
Minggu, 1 Juni	26,9–27,9	24,2–24,9	25,7–27,5	25,7–26,6	0,19–0,50	<0,40
Senin, 2 Juni	29,8–30,7	24,3–25,7	26,5–27,7	29,8–30,9	0,74–0,89	0,45–0,59
Selasa, 3 Juni	28,0–30,2	24,3–26,2	26,2–27,7	29,0–29,7	0,73–0,86	0,47–0,61
Rabu, 4 Juni	28,9–30,7	25,4–27,3	26,3–27,2	30,5–31,5	0,73–0,84	0,49–0,64
Kamis, 5 Juni	30,4–31,8	25,3–26,8	27,6–29,2	32,0–33,2	0,70–0,91	0,50–0,70

The generally high R^2 values (0.70–0.91) confirm that indoor temperature fluctuations are strongly influenced by outdoor temperature, with every 1°C increase in outdoor temperature followed by a 0.4–0.7°C increase in indoor temperature. An exception occurs on Sundays (R^2 0.19–0.50), when internal factors such as natural ventilation are more dominant. Indoor temperatures during the afternoon and early evening generally exceed the SNI thermal comfort threshold; therefore, passive strategies such as shading, cross-ventilation, and materials with high thermal mass are highly recommended, particularly on the west-facing side.

2. Analysis of Humidity in the Prayer Room Over a Daily Cycle

Relative humidity (RH) inside the prayer room follows a pattern opposite to that of temperature: the highest values occur at night through the early morning, and the lowest during the day when temperatures peak. Overall, indoor RH remains high (averaging 74–88%) and is more stable than outdoor RH, indicating the building's mass's ability to dampen external humidity fluctuations.

The west and north sides are slightly drier during the day, consistent with greater temperature increases in those areas, while the south and east sides tend to be more stable. Sunday (June 1) and Monday (June 2) recorded the highest and most stable RH, while Thursday (June 5) showed the greatest range of fluctuations. A quantitative summary is presented in Table 2.

Table 2: Summary of daily humidity levels in the prayer room and their correlation with outdoor relative humidity.
Source: Field Data

Hari / Tanggal	RH Maks Dalam (%)	RH Min Dalam (%)	RH Rata² (%)	R^2	Slope
Kamis, 29 Mei	85,6–89,7	71,3–73,3	77,2–81,6	0,81–0,91	0,47–0,65
Jumat, 30 Mei	86,1–88,6	71,4–74,7	79,1–84,8	0,70–0,81	0,49–0,62
Sabtu, 31 Mei	88–92	72–76	77–85	0,15–0,75	—
Minggu, 1 Juni	87,6–88,6	82,3–83,8	84,0–86,3	0,61–0,77	—
Senin, 2 Juni	≤97	83–85	84–88	>0,70	0,47–0,59
Selasa, 3 Juni	93–95	73–76	74–83	0,75–0,78	—
Rabu, 4 Juni	84–88	72–76	74–81	0,73–0,83	0,32–0,61
Kamis, 5 Juni	≥80	67–75	70–84	>0,80	—

The correlation between outdoor and indoor relative humidity (RH) is generally strong (R^2 0.61–0.91), with a 1% increase in outdoor RH followed by a 0.3–0.65% increase in indoor RH. Differences in response between directions reflect the influence of opening orientation and natural ventilation patterns. Stable high humidity supports thermal comfort but has the potential to cause a stuffy feeling as the number of worshippers increases, so ventilation optimization remains necessary.

3. The Effect of Wind Movement and Speed on Thermal Performance

Outdoor wind speed and direction play a significant role in the thermal performance of the prayer room. During periods of higher wind speeds, there is a decrease in indoor temperature and an increase in cross-ventilation effectiveness, in line with stable humidity and a reduction in internal heat load.

Wind rose data (Figure 5) for May 29–June 5, 2025, show that the dominant winds originate from the west to southwest sectors with speeds of 2.1–5.7 m/s. This orientation aligns with the mosque's ventilation design: 80-cm-high lower vents surrounding the building serve as fresh air inlets, while 30-cm-high upper vents on the west and east sides function as hot air outlets. This combination creates effective cross-ventilation, as evidenced by the stable indoor temperature despite rising outdoor temperatures.

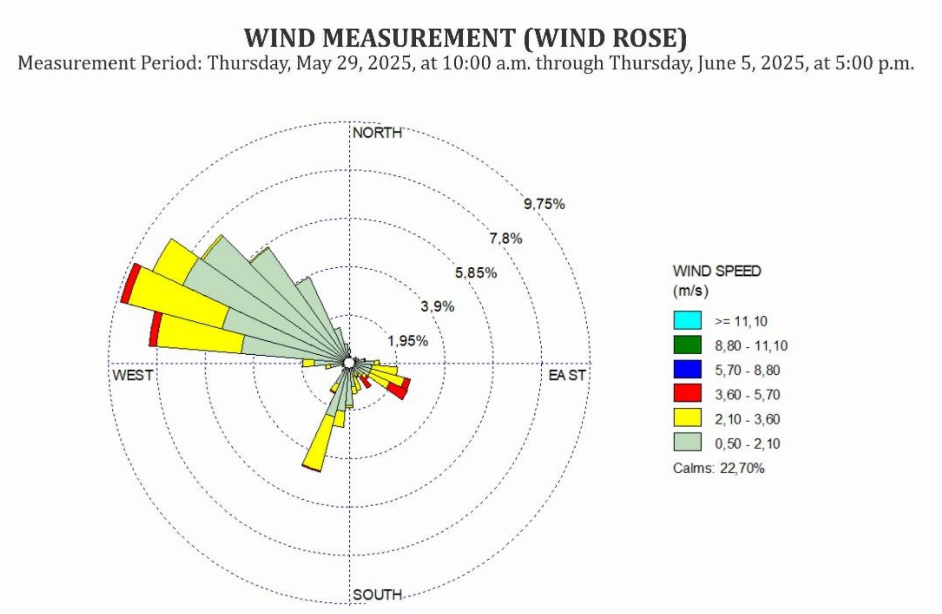

Figure 5: Wind Measurement (Wind Rose)
Source: Field Data

The architectural cross-section of the mosque (Figure 6) confirms that natural airflow moves from west to east and from southwest to northeast, passing through the lower vents and exiting through the upper vents. This integration of the dominant wind direction and the ventilation layout is the primary factor in achieving thermal comfort in the prayer hall, while also demonstrating that the mosque's architectural design is responsive to local microclimatic conditions. Strengthening passive strategies on the west side—particularly additional shading—is still recommended to mitigate the mid-afternoon heat peak.

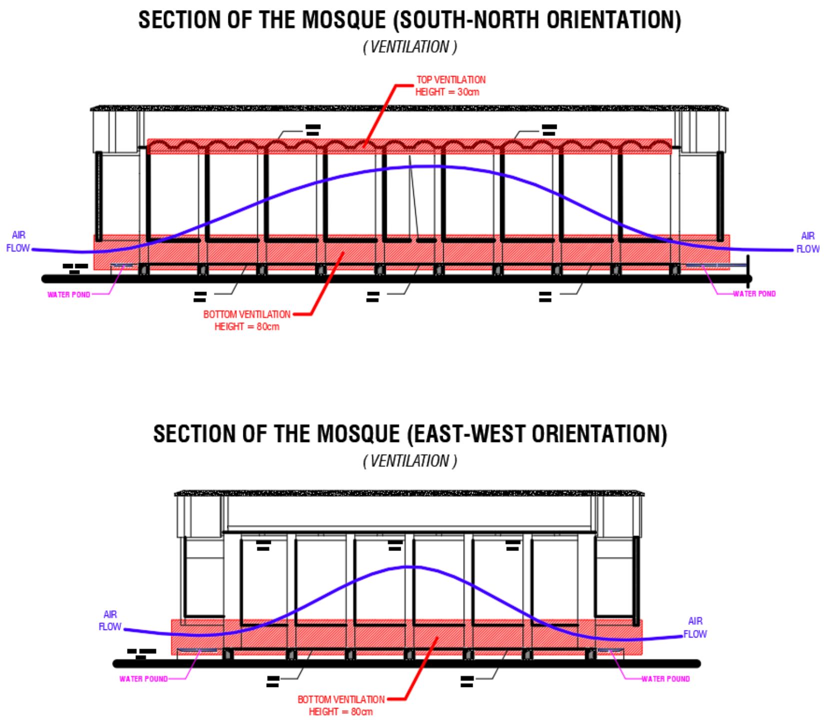

Figure 6: Architectural Cross-Sections of a Mosque
Source: Field Data

4. Interpretation of Results

The results of the eight-day observation period indicate that the temperature and humidity in the prayer hall of the Nurul Yaqin Mosque exhibit fairly significant daily fluctuations, though they tend to be more stable than outdoor conditions. The maximum indoor temperature recorded was 31.8°C, while the minimum was 24.2°C; relative humidity ranged from 68% to 88%. These temperature and humidity patterns were influenced by cross-ventilation facilitated by upper and lower openings, as well as prevailing winds from the west and south.

These conditions align with SNI 03-6572-2001, which states that thermal comfort in public spaces is significantly influenced by air temperature, humidity, and wind speed. In the context of a mosque, the temperature in the prayer hall does tend to be slightly above the comfort standard (22.8–25.8°C), but it remains within the tolerance limits for light activities such as worship. These findings are supported by studies (Iqbal, Atthaillah, Nayan, et al., 2024) and (Chandra & Azizah, 2023), which state that thermal comfort in naturally ventilated buildings in tropical climates is significantly influenced by airflow through openings, as well as outdoor temperature and humidity. The correlation between outdoor temperature and humidity and indoor conditions was also evident in this observation.

Furthermore, the finding that prevailing westerly and southerly winds can lower indoor temperatures and maintain humidity aligns with the study by Iqbal, Atthaillah, Nayan, et al. (2024), which underscores the importance of cross-ventilation design to maximize air circulation and control temperature in tropical buildings. This was also observed in a study (Syamsiyah & Izzati, 2021), where suboptimal airflow led to high temperatures and a stuffy feeling inside the mosque.

5. Implications for Mosque Design in Tropical Climates

Based on the analysis results, it can be concluded that cross-ventilation design, an adequate ratio of openings in strategic positions (top and bottom), and the orientation of openings toward the prevailing wind direction are crucial for thermal comfort in mosques in tropical climates. The addition of water features and vegetation around the mosque has been shown to help lower air temperature through a microclimate cooling effect, as also recommended by (Wulandari1 & Zulfikri, 2024) and (Asyrafi & Indrawati, 2022).

This is also supported by the findings of (Nasrul et al., 2024) and (Luthfiyah Zahran et al., 2023), which emphasize the importance of adjusting opening designs, incorporating vegetation, and optimizing natural ventilation to create thermal comfort in tropical public spaces, including mosques. Without such measures, indoor temperatures tend to exceed the comfort zone, humidity can rise excessively, and user comfort is not achieved.

6. Management Recommendations

Based on the research findings, mosque management in tropical climates must be conducted in an integrated and adaptive manner to achieve optimal thermal comfort. One of the key aspects is the maintenance and optimization of ventilation. All upper and lower ventilation openings must be kept clean at all times and ensured to remain unobstructed by dust, dirt, or other objects. Clean and fully open ventilation will ensure optimal air circulation within the prayer hall, allowing excess heat and humidity to be easily expelled.

Additionally, adaptive adjustment of ventilation openings is crucial. Openings must be dynamically adjusted according to environmental conditions—such as opening vents wider when strong winds prevail, and closing them partially or completely during high humidity or heavy rainfall to prevent humid air or rainwater from entering the space. These adjustments aim to maintain air quality and the thermal comfort of worshippers at all times.

Efforts to optimize the landscape and water features around the mosque are also highly recommended. Planting vegetation and adding ponds or other water features have been proven to lower the air temperature around the building through a microclimate cooling effect. The presence of greenery and water not only beautifies the environment but also actively helps create cooler, fresher air before it enters the prayer hall.

Effective management also requires routine monitoring. Periodic monitoring of temperature, humidity, and wind speed—both indoors and outdoors—must be conducted to serve as the basis for evaluating future management strategies. This monitoring will provide accurate data to determine the effectiveness of ventilation, openings, and landscaping in ensuring the mosque's thermal comfort.

Finally, adjustments to building materials also require attention. Selecting materials that can reflect heat and possess good thermal mass will greatly help maintain indoor temperature stability, ensuring that temperature fluctuations caused by changes in outdoor weather are not immediately felt inside the prayer hall.

By implementing these recommendations in an integrated manner, mosques in tropical climates can create a cool, healthy, and comfortable worship environment. Maintaining thermal comfort not only enhances the quality of worship for congregants but also supports energy and environmental sustainability in mosque buildings.

V. CONCLUSION

This study aims to evaluate the thermal performance of the prayer hall at the Nurul Yaqin Mosque in Palu, which is located in a tropical climate, with a focus on analyzing temperature, humidity, wind movement, and the mosque's natural ventilation design. Intensive measurements and analysis were conducted over eight consecutive days, including the collection of data on temperature, humidity, and wind movement and speed, both indoors and outdoors.

Based on the measurement results, the temperature inside the prayer hall during the observation period ranged from a minimum of 24.2°C to a maximum of 31.8°C. Daily temperature fluctuations tended to follow the outdoor temperature pattern but were moderated by the building's thermal mass and the cross-ventilation system in place. Relative humidity indoors ranged from 68% to 88%, with a pattern of decline during the day and a subsequent rise at night. Although the temperature and humidity inside the prayer room remained above the standard comfort zone for tropical buildings, their values tended to be more stable and well-maintained compared to outdoor conditions.

An analysis of wind direction and speed shows that the prevailing winds come from the west and south. The presence of lower vents on all sides of the building, as well as upper vents on the west and east sides, enables effective cross-ventilation. When outdoor wind speeds increase, indoor temperatures tend to drop, and humidity becomes more stable. These results underscore the importance of orienting openings and designing natural ventilation systems that respond to prevailing wind directions.

The incorporation of landscape elements such as water features and vegetation around the mosque also contributes to lowering air temperature through microclimate cooling effects. The integration of cross-ventilation design, strategic openings, and landscape arrangement has proven effective in enhancing thermal comfort in the prayer hall, even under hot and humid outdoor conditions.

Management recommendations include: (1) periodic maintenance and optimization of ventilation to ensure unobstructed airflow; (2) adaptive adjustment of ventilation openings based on the time of day and wind direction; (3) optimization of the landscape and addition of water features around the building; (4) routine monitoring of temperature, humidity, and wind parameters; and (5) adjusting building materials to support thermal efficiency. These steps are crucial for maintaining and improving the thermal comfort of mosques in tropical climates.

Overall, this study confirms that a combination of cross-ventilation design, wind path optimization, landscaping, and adaptive management is highly effective in maintaining the thermal comfort of mosque prayer spaces in tropical regions. These findings are expected to serve as a reference for mosque managers and designers in implementing design and management strategies focused on comfort, health, and energy efficiency in tropical environments.

REFERENCES

[1]. Alauddin, A., & Mustamin, T. (2020). Karakteristik Temperatur Udara Terhadap Kenyamanan Termal Di Masjid Agung Luwuk Banggai. Jurnal Linears, 2(2), 49–54. https://doi.org/10.26618/j-linears.v2i2.3121

[2]. Asyrafi, H., & Indrawati. (2022). Komparasi Indikator Kenyamanan Penghawaan Alami pada Beberapa Tipe Bukaan di Masjid Baiturrahim Kuala Tungkal. Jurnal Seminar Ilmiah Arsitektur III, 605–613. http://siar.ums.ac.id/ diakses pada 21 Mei 2024

[3]. Chandra, D. D., & Azizah, R. (2023). Pengukuran kenyamanan termal pada Masjid Fadlurrahman Universitas Muhammadiyah Surakarta. Jurnal Hirarchi, 20(1), 10–15.

[4]. Delyuzir, R. D., Sadewo, R. P., Afriliani, A., Khaliq, I., & Hartanto, K. (2023). Studi Perbandingan Kenyamanan Termal Indoor dan Outdoor Stasiun MRT Jakarta (Studi kasus: Stasiun MRT Bundaran HI dan MRT ASEAN). Local Engineering, 1(2), 67–72. https://doi.org/10.59810/lejlace.v1i2.76

[5]. Ikramina, F., Sari, L. H., & Sawab, H. (2020). Evaluasi Tingkat Kenyamanan Termal Bangunan Museum Tsunami Aceh. Jurnal Ilmiah Mahasiswa Arsitektur Dan Perencanaan, 4(3), 67–71.

[6]. Iqbal, M., Atthaillah, Nayan, A., & Indriani, L. (2024). The Effect Of Openings Type On Indoor Temperature Of Naturally Ventilated Buildings In The Tropical Climate. Journal of Applied Science and Engineering, 28(8), 1769–1777. https://doi.org/10.6180/jase.202508_28(8).0014

[7]. Iqbal, M., Atthaillah, Safyan, A., Indriani, L., & Sina, A. M. (2024). Kenyamanan Termal pada Bangunan Berventilasi Alami di Iklim Tropis. NATURE : National Academic Journal of Architecture, (December). https://doi.org/10.24252/nature.v11i2a3

[8]. Luthfiyah Zahran, N., Salsabila, K., Ramadhan, T., & Maknun, J. (2023). Analisis Kenyamanan Termal Bangunan Masjid SMA Di Kota Bandung. Tesa Arsitektur, 21, 60–71.

[9]. Nasrul, Nur, D. E., Kausarani, R., Amdah, M., Afandi, Musyawarah, R., Medar, M. N., Diar Hasja, A., & Maru, R. (2024). Studi Analisis Hubungan Iklim Mikro Terhadap Kondisi Kenyamanan Termal Ruang Kuliah Jurusan Geografi FMIPA Universitas Negeri Makassar. Indonesian Journal of Fundamental and Applied Geography, (July).

[10]. Ngurah Aritama, A. A., & Pradnya Paramitha, I. A. S. (2023). Faktor-Faktor Yang Berpengaruh Terhadap Kenyamanan Termal Rumah Tradisional Desa Tenganan Pegringsingan. Jurnal PATRA, 5(1), 28–36. https://doi.org/10.35886/patra.v5i1.461

[11]. Prabowo Sulistiawan, A., Wandri, S., Fauzan, E., & Nizar Bahari, M. (2020). Thermal Comfort Investigation On Holy Mosque In Bandung Case Study : Lautze 2 Mosque Bandung. Journal of Architectural Research and Education, 2(1), 82. https://doi.org/10.17509/jare.v2i1.24105

[12]. Sekar Larasati, N., & Setyowati, S. (2023). Identifikasi Kenyamanan Termal Ruang Kelas pada Bangunan Sekolah Menengah Atas (Studi Kasus: SMA Muhammadiyah Kudus). Prosiding (SIAR) Seminar Ilmiah Arsitektur, 239–248. https://proceedings.ums.ac.id/index.php/siar/article/view/2884

[13]. Syamsiyah, N. R., & Izzati, H. N. (2021). Strategi Kenyamanan Termal Masjid (Studi Kasus Masjid Al-Kautsar Kertonatan, Sukoharjo, Jawa Tengah). Langkau Betang: Jurnal Arsitektur, 8(2), 98–109. https://doi.org/10.26418/lantang.vnin.This

[14]. Wulandari1, R., & Zulfikri. (2024). Analisa Penghawaan dan Pencahayaan terhadap Kenyamanan Termal pada Rindang Cafe and Eatery Palembang. Teks.Tu-Reka, 2, 86–93.
[15]. Zuraihan, Munandar, A., & Muliani, F. (2023). Analisis Indeks Kenyamanan Ruang Dengan Pendekatan Iklim Dan Material. 21(Desember), 135–149. http://dx.doi.org/1025105/agora.v20i2.18128