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Evaluation of Thermal Conditions Using Temperature, Relative Humidity, and Air Velocity Parameters in the At-Taqwa Mosque Hall, Universitas Muhammadiyah Semarang

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Abstract. Thermal comfort is an important factor in the design of a mosque hall used by many congregants for long periods of time. The At-Taqwa Mosque hall of Universitas Muhammadiyah Semarang is frequently used for various activities, but its thermal condition has never been evaluated. This study aims to evaluate the hall's thermal condition based on parameters of air temperature, relative humidity, and air velocity. The method used is a descriptive quantitative approach. Data collection was carried out by measuring temperature, humidity, and air velocity directly at five points from 06.00–18.00 WIB. Analysis was carried out by comparing the results with thermal comfort standards in humid tropical climates (ASHRAE 55 and SNI 03-6572-2001). The results showed a temperature range of 26.4°C–29,9°C and a relative humidity of 76.8%–88.5%. Wind speed ranged from 0.15–0.5 meters/second. The measurement results showed that the air temperature experienced a gradual increase from an average of 26.4°C in the morning to a peak of 29,9°C during the day. Relative humidity showed a decreasing trend from an initial value of 88.5% to as low as 76.8% and increased towards the afternoon, in line with the increase in temperature. Air velocity increased from 0.15 meters/second to a maximum of 0.5 meters/second at midday. These findings emphasize the importance of planning a strategy for managing air temperature, relative humidity, and air velocity parameters in achieving thermal comfort in a room. Optimization strategies for air circulation and natural ventilation management in closed spaces with passive and active ventilation system designs for tropical public spaces to support comfort, energy efficiency, and environmental health in the context of worship. The conclusion is that the mosque hall has the potential for thermal discomfort, so passive design improvements such as cross ventilation and shading are needed.

Keywords: thermal comfort; air temperature; relative humidity; air velocity; natural ventilation

1. Introduction

The mosque not only functions as a place of worship, but also as a center for community social activities, which can increase interaction and harmony [1]. Thermal comfort is an important parameter in assessing indoor environmental quality, especially in buildings with public space functions such as mosques [2]. To support these various functions optimally, the mosque building must be able to provide comfort for its users [3], [4]. This thermal comfort is a mental condition that indicates a person's satisfaction with their thermal environment [5]. In buildings that function as public spaces, such as mosques, thermal comfort is very important.

Indonesia, with its humid tropical climate, is characterized by relatively high air temperatures, high humidity, and wind speeds that tend to be low [6]. High humidity can hinder air circulation, which directly affects thermal comfort and often causes complaints of heat from the congregation, even when the fan is turned on [7]. This condition ultimately impacts concentration, devotion to worship, and even the health of the congregation. Crowd density can also increase indoor temperatures, especially in the center of the mosque [8].

One of the main challenges in managing thermal comfort in mosques is the ventilation design, which relies on natural ventilation without the aid of mechanical cooling systems. Air temperatures often remain high and fall into the uncomfortable category [9]. This thermal discomfort is often caused by architectural design factors, such as building orientation and window spacing, which can cause hot air to become trapped indoors [7]. In these conditions, physical environmental parameters such as air temperature, relative humidity, and air speed become the main determining factors in creating thermal comfort.

Previous research has emphasized the importance of evaluating thermal conditions in enclosed spaces by considering these factors. International standards such as ASHRAE 55 and ISO 7730 emphasize that thermal comfort is influenced not only by temperature, but also by relative humidity and airflow around the human body [10]. Too high relative humidity will inhibit sweat evaporation, making it difficult for the body to dissipate heat. Conversely, sufficient wind speed can increase evaporation and help create a cool sensation [11].

Universitas Muhammadiyah Semarang (UNIMUS) houses the At-Taqwa Mosque as one of its primary facilities for worship and academic activities. The main hall of the At-Taqwa Mosque, located on the first floor, is a spacious, enclosed space with natural air circulation and air conditioning. However, no study has systematically evaluated the thermal conditions within the mosque based on direct measurements. Microclimate monitoring at various points within the mosque can provide important information regarding temperature and humidity distribution, as well as potential improvements to the natural ventilation system (Figure 1).

Based on this, the main objective of this study is to evaluate the thermal conditions inside the hall of the At-Taqwa Mosque, Universitas Muhammadiyah Semarang, through analysis of air temperature, relative humidity, and air velocity parameters. Specifically, the objectives of this study include: (1) measuring and analyzing the distribution of temperature and relative humidity inside the mosque hall at various points (four corners and the center of the room) in the time span from morning to evening; (2) knowing the daily trends of temperature, humidity, and wind speed parameters during the observation period from 06.00 to 18.00 WIB; (3) obtaining results that can be used as a basis for determining strategies in optimizing parameters to achieve room comfort.

This research is expected to provide recommendations regarding the management of natural ventilation and thermal comfort for hall spaces based on the results of microclimate analysis. By understanding thermal distribution patterns and indoor microclimate dynamics, this research is expected to provide scientific and practical contributions in an effort to create more comfortable, energy-efficient, and environmentally friendly mosque hall spaces.

a b

Figure 1 At-Taqwa Unimus Mosque from the air, a. front view and b. rear view
(Source: https://ftik.unimus.ac.id/masjid-2/)

2. Methods

This study uses a descriptive quantitative approach to evaluate the thermal conditions inside the At-Taqwa Mosque Hall at Universitas Muhammadiyah Semarang. Data collection was conducted directly through field measurements of three physical environmental parameters, namely air temperature (°C), relative humidity (%), and air velocity (meters/second), in accordance with standard indoor thermal measurement guidelines.

2.1. Data Collection Method

Data were obtained from measurements of air temperature, relative humidity, and wind speed at five points within the At-Taqwa Mosque hall: the four corners and the center of the room. These measurements were conducted on Sunday, July 6, 2024, from 6:00 a.m. to 6:00 p.m. Western Indonesian Time (WIB), in the At-Taqwa Mosque Hall of UNIMUS, Semarang City, Central Java. The location was chosen because it serves as a prayer and campus activity space with the potential for high thermal loads. Five measurement points were determined: the four measurement points in the room (measurement points 1, 2, 4, and 5) and the center of the room (measurement point 3), with the aim of obtaining an even distribution of temperature and humidity throughout the hall. The parameters measured included: (a) air temperature (°C): measured using a standard digital thermometer calibrated before use; (b) relative humidity (%): measured simultaneously with temperature using a thermohygrometer; and (c) air speed (meters per second): measured using a digital anemometer (Figure 2).

Figure 2 Instruments for measuring air temperature, air humidity, and wind flow speed

2.2. Data Analysis Method

Data were analyzed quantitatively using descriptive statistics. Average hourly temperature, humidity, and air velocity were compared to thermal comfort standards issued by ASHRAE Standard 55 and SNI 03-6572-2001. The measurement data obtained were then averaged from five points, compiled into a table, and analyzed quantitatively 3).

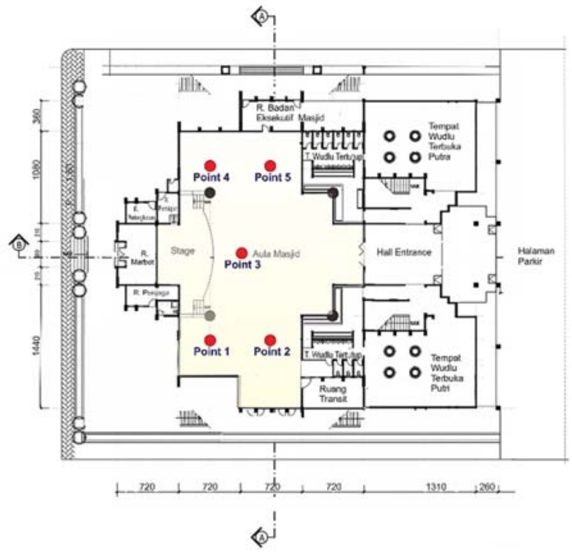

Figure 3 Measurement points for temperature, humidity, and wind speed
(Source: author's reproduction, 2025)

3. Results and Discussion

3.1. Temperature (°C)

The data shows that the temperature inside the mosque hall gradually increased from morning to morning. At 6:00 a.m., the average temperature was 26.4°C, reflecting the still cool morning conditions. The temperature continued to rise until it reached 29,9°C at 1:00 p.m., marking the daily peak. Afterward, the temperature began to decline slowly, reaching 27.9°C at 6:00 p.m. The temperature at all five measurement points increased from morning to afternoon and decreased until evening. This indicates that the temperatures at all five measurement points were nearly identical, with only minor differences (Figure 4).

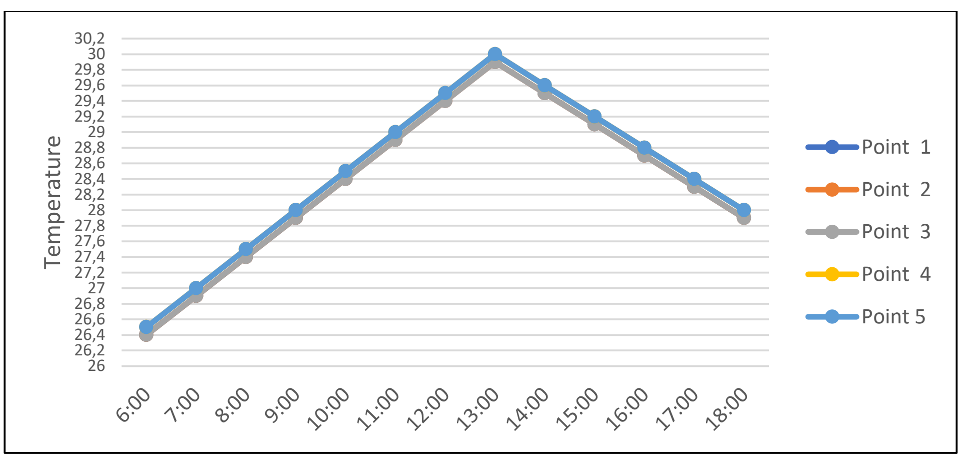

Figure 4 Temperatures at the five measurement points from 6:00 AM to 6:00 PM
(Source: author's analysis, 2025)

An analysis of the average temperature of the five measurement points shows that at measurement points 1, 2, and 3, the average temperature is 28.36 0C. Meanwhile, at points 4 and 5, the temperature is higher, namely 28.46 0C. These temperatures indicate that the five measurement points in the At-Taqwa Mosque hall are included in the uncomfortable zone for mosque congregations who want to carry out activities in the hall (Figure 5).

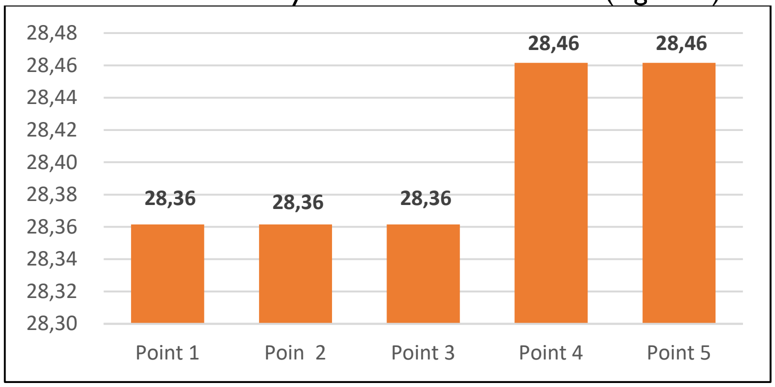

Figure 5 Average temperature of the five measurement points
(Source: author's analysis, 2025)

This pattern is consistent with the building's exposure to sunlight throughout the day, where temperatures increase due to heat accumulation in the building's structural elements (roofs and walls). Based on thermal comfort standards (ASHRAE 55 and SNI 03-6572-2001), the ideal temperature in light activity spaces such as prayer rooms ranges from 23°C to 27°C. Therefore, temperatures during most of the observation periods were above the comfort limit, particularly between 10:00 and 15:00.

3.2. Relative Humidity (%)

The humidity inside the mosque hall showed a downward trend throughout the morning. The initial value at 6:00 a.m. was 88%, quite high due to the influence of morning dew and the tropical environment. The humidity decreased to a low of 77.5% at 1:00 p.m., then increased again in the afternoon to 83.5% at 6:00 p.m. (Figure 6).

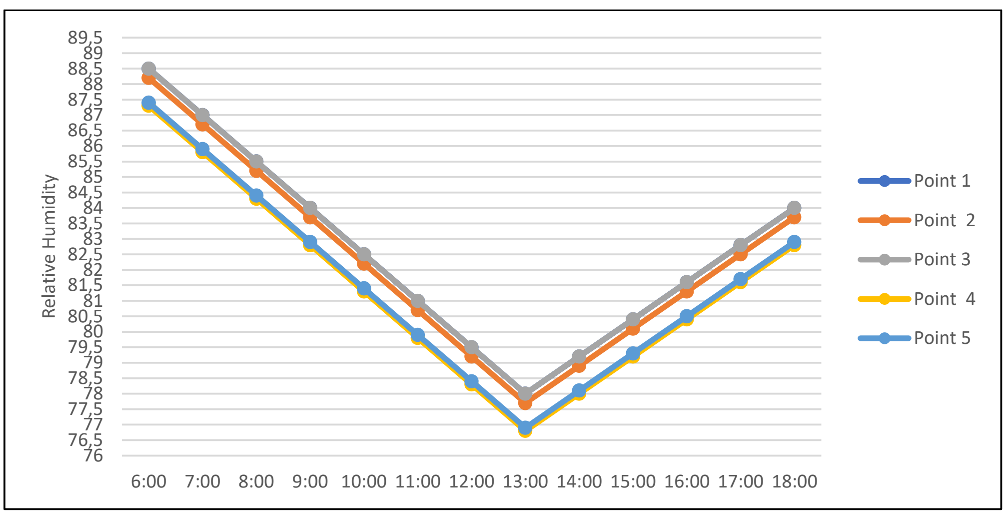

Figure 6 Relative humidity at the five measurement points from 6:00 AM to 6:00 PM
(Source: author's analysis, 2025)

Analysis of the average relative humidity at the five measurement points shows that measurement points 1 and 3 have an average humidity of 82.62%. Meanwhile, at point 2, the humidity is 82.32%. The moisture at measurement point 4 is 81.42% and at measurement point 5, it is 81.52%. This relative humidity indicates that all five measurement points in the At-Taqwa Mosque hall are in the less comfortable zone (Figure 7).

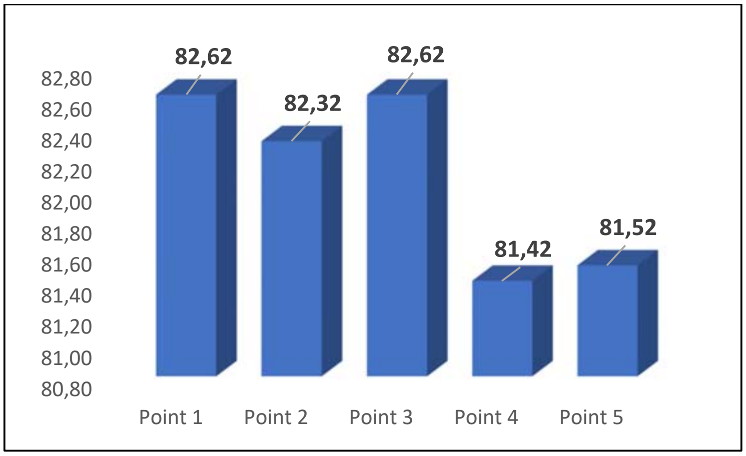

Figure 7 Average relative humidity of the air at the five measuring points in the mosque hall

The decrease in humidity is caused by an increase in air temperature; warm air has a greater capacity to hold water vapor, resulting in a decrease in relative humidity. Even when humidity is within the comfort tolerance range (40%–60%), the combination of high temperatures can still compromise comfort levels. High humidity in the morning and evening can potentially create a stuffy or sticky feeling because sweat evaporation from the skin is less efficient.

3.3. Air Velocity (meters/second)

Air velocity was measured using a digital anemometer. In the morning (6:00 AM), air velocity was 0.15 meters/second, then gradually increased to 0.5 meters/second at 12:00 PM. After that, the velocity decreased to 0.2 meters/second at 6:00 PM. Air velocity is still considered within the thermal comfort limits for a prayer room. Air velocity does not directly lower the air temperature (°C). However, moving air accelerates the evaporation of sweat from the skin, which has a cooling effect on the body. The lack of cross-ventilation or air circulation within the building makes this air velocity uneven and less effective in creating a sense of comfort.

Measurements taken at the five points revealed differences in temperature, humidity, and air velocity at each point. The thermal conditions of the At-Taqwa Mosque hall were influenced by the measured parameters. The presence of air flow or circulation within the room can affect temperature perception [12][13]. The lower the air movement at the five measurement points, the higher the effective temperature. Conversely, the lower the effective temperature at the five measurement points, the higher the air movement. Increasing the speed of air movement is a strategy for improving indoor thermal comfort [14][15]. The thermal conditions of the mosque hall vary significantly during worship services, religious studies, or other events involving large crowds. This significantly differs from the effective temperature when the mosque is empty. The primary reason for this temperature increase is the density, or the large number of people present in the room [8]. This increase in thermal conditions occurs because the human body itself evaporates, or evaporates, its metabolism, so crowded areas also contribute to the increase in indoor thermal conditions. To maintain a stable temperature (homeostasis), the body releases this excess heat into the environment through the evaporation of sweat from the skin [16]. The crowd effect in a location filled with many people, the heat and water vapor released from each person's body will increase the overall temperature and humidity of the room [17].

4. Conclusions

This study evaluated the thermal conditions inside the At-Taqwa Mosque hall at Universitas Muhammadiyah Semarang using air temperature, relative humidity, and air velocity parameters from 6:00 AM to 6:00 PM WIB. Air temperature increased significantly from morning to noon, with the lowest temperature recorded at 26.4°C at 6:00 AM and the highest temperature reaching 29.9°C at 1:00 PM. This temperature increase occurred evenly across all observation points. Relative humidity showed a decreasing pattern inversely proportional to temperature, from 88.0% in the morning to as low as 77.5% at noon, while in the afternoon it increased to 83.5%. The decrease in humidity followed the rising temperature trend, indicating a significant effect of room heating on the water vapor content in the air. Wind speed increased gradually from morning to noon, starting from 0.15 meters/second to 0.5 meters/second at noon. This indicates an increase in natural air circulation in the room as the outdoor temperature increases.

In general, the thermal conditions inside the mosque are still within the limits of natural thermal comfort, especially in the morning. However, conditions during the day show potential discomfort due to high temperatures and low humidity. The importance of planning a strategy for managing air temperature, relative humidity, and air velocity parameters in achieving thermal comfort in the room. Optimization strategies for air circulation and natural ventilation management in closed spaces with passive and active ventilation system designs for tropical public spaces to support comfort, energy efficiency, and environmental health in the context of mosque activity spaces with passive design improvements such as cross ventilation and shading.

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