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THE INFLUENCE OF ORIENTATIONS AND BUILDING DESIGNS ON THERMAL PERFORMANCE IN TRADITIONAL HOUSES, IN GAYO HIGHLAND REGION, ACEH, INDONESIA

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ABSTRACT

Gayonese traditional houses are called Umah Pitu Ruang (UPR) designed to adapt to the climatic conditions of the Gayo highland region in Indonesia. Gayo highland is well known for the cool humid climate zone in Aceh Province which is different from the lowland of Aceh i.e. hot humid. As a residential function, this building requires an adequate level of thermal comfort so that users can carry out their activities properly. This study aims to evaluate whether the thermal comfort performance in Umah Pitu Ruang (UPR) meets the standard; and to identify the influence of house orientation and building design in the thermal indoor environment. The research method used is a quantitative method obtained from the results of field observations and the results of measuring thermal comfort variables in the form of air temperature (Ta), relative humidity (Rh) and wind speed (v)

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in both Umah Pitu Ruang. Later the measurement results will be compared with Indonesian thermal comfort standard namely 03-6572-2001. The results showed that the thermal performance such as air temperature, relative humidity, and wind speed in Gayonese traditional houses did not meet the SNI standard. . The study also indicates that the orientation of the buildings is influential on thermal performance. Openings orienting west and east work more effectively in warming the interiors while at the same time the airflow running across the rooms. In contrast, orienting the openings to the north and the south is able to get slightly lower air temperature which is essential to be reduced during the day to be comfortable.

Keywords: *Thermal Performance, Umah Pitu Ruang, Gayo HighLand, Orientations, Building Designs*

INTRODUCTION

Home is a very important need for human life. According to Pawestri (2019), a house is not only a building (structural) but also a place of residence that meets the requirements of a decent life and is seen in various aspects of community life. As a place to live and carry out daily activities, the house needs to be designed by paying attention to all aspects of the condition of comfort such as the aspect of thermal comfort. According to Nurazizah & Wibawa (2018), thermal comfort is a condition of temperature or environmental humidity that is appropriate for humans so that later they can carry out activities and are the fundamental things needed by humans. In recent years, the problem of the thermal comfort of builders has begun to be considered both by the designer and by building users.

At present, architectural buildings in Indonesia have begun to be designed by taking into account the characteristics of existing climate conditions. This is of course done so that the response to climatic conditions can be poured into a building design so that later the response can be paid attention to in terms of aspects of thermal comfort itself. This design response can be seen in Indonesian cities that have implemented it. One of them is the city of the Gayo Highland region which is located in Central Aceh Regency, Indonesia.

The Gayo Highland region is one of the cities in Indonesia that has a wet tropical climate with a constant air temperature of an average of 20ºC. As a city with a wet tropical climate, it is indicated that these climate conditions can cause thermal discomfort and can even interfere with human health because it is lower than the optimal human air temperature for activities which is around 20-27 ° C. Air temperature affects the condition of the inhabitants of the building. Haoran Ning (2016) said that if the air temperature is too cold, the user of the building will be shivering and cannot move well. Dahlan & Gital (2016) also argue that if the air temperature is too hot, the building will experience thermal stress or the effect of hysteresis.

The Gayo Highland has a unique historical architecture i.e. the historical kingdom of Linge which in its time left various architectural artefacts. One of the relics of this artefact can be seen in the "Umah Pitu Ruang (UPR)" which is a traditional house located in the village of Buntul Linge. UPR is designed by making adjustments to climate conditions in the wet topic area. In Buntul Linge Village, two Gayonese traditional houses were built in different periods and building orientations. Each orientation in UPR has east-west and north-south directions. On the other hand, differences in building design can be seen in the openings used, the material applied and the amount of space applied.

A **B**

Figure 1. Umah Pitu Room of West Eastern Orientation (UPR1) (A) and North-South Orientation (UPR2) (B)

Source: Author

This traditional house is big which can accommodate up to seven families depending on the number of bedrooms. As a residential function, differences in orientation and design of this building are certainly interesting to be evaluated considering that every space in UPR has different activities with the needs of the thermal comfort levels that are also different. With this evaluation, it is very possible that through the difference in orientation direction and building design, there is space that is by the level of its thermal comfort, but there is also space that does not match the level of thermal comfort. Therefore, the problem discussed in this study is how to evaluate thermal comfort based on differences in the orientation and design of the UPR in Buntul Linge Village in accordance with the Indonesian National Building Standards or SNI 03-6572-2001.

Based on the background description above, the main objective of this study is to evaluate whether the thermal comfort performance in Umah Pitu Ruang (UPR) meets the standards set by SNI 03-6572-2001; and to identify the influence of house orientation and building design in the thermal indoor environment.

Thermal Comfort

Thermal comfort is a condition felt by humans as a result of conditions in the surrounding environment. The level of thermal comfort becomes important in a space in the building considering that a building is a shelter for humans who should be able to provide comfort to its inhabitants (Ahmad, 2020). Latifah (2015) states that the principle of thermal comfort is the achievement of a balance between the temperature of the human body with the surrounding temperature. If later there will be a significant difference between the temperature of the human body and the environment, it will cause discomfort that is realised through the heat or cold that the body feels. The purpose of every planning of a building is to create maximum comfort for humans. However, there is no objective benchmark for convenience. The body has an ability to be adaptive against the thermal environment which depends on personal and environmental factors. According to Eric (2017), the factors that influence the level of thermal comfort in a closed room are as follows:

a. Air temperature
b. Humidity

c. Wind velocity
d. Clothing insulation
e. Activity

Thermal comfort is directly related to the climate and heat and some other aspects that affect the thermal comfort itself. Based on the Indonesian standard i.e SNI 03-6572-2001 (Table 1), the optimal convenient limit of effective temperature in the equator ranges between temperatures of 22.8ºC-25.8ºC as shown in Table 1 below. As for the tropical region, the recommended relative humidity is between 40% ~ 50%, but for spaces with solid people such as meeting rooms, relative humidity is still allowed to range between 55% ~ 60%.

Table 1. The Thermal Comfort range based on the Indonesian Standard

Sensation	Effective Temperature (ET)
Comfortably cool	20,5ºC - 22,8ºC
Optimally comfortable	22,8ºC - 25,8ºC
Comfortably warm	25,8ºC - 27,1ºC

Source: SNI 03-6572-2001 (2001)

In addition to temperature and humidity, wind speed also affects a person's thermal comfort level. According to SNI 03-6572-2001 regarding the procedure for the design of the ventilation and air conditioning system in buildings, to maintain a comfortable condition, the air velocity that falls on the head should not be greater than 0.25 m/sec and should be smaller than 0.15 m/sec. This air velocity can be greater than 0.25 m/sec depending on the dry bulb temperature (DBT). The higher DBT, the faster the wind speed needed to give more thermal comfort sensation (Table 2).

Table 2. The Rate of Air Velocity and Coolness

Windspeed (m/s)	0,1	0,2	0,25	0,3	0,35
DBT-Dry bulb temperature (ºC)	25	26,8	26,9	27,1	27,2

Source: Author

Characteristics of Gayo Highland

The Gayo Highlands or Gayo Land is an area located in the ridges of the Bukit Barisan mountains that stretch along the island of Sumatra in Indonesia. Administratively, the Gayo Highlands covers the districts of

Central Aceh, Bener Meriah, and Gayo Lues, which are all parts of the Aceh province. Takengon, the capital city of Central Aceh, is quite close to Bener Meriah district which has similar topography and climate. The elevation is about 1350 metres above sea level which is higher than Blangkejeren, the capital city of Gayo Lues (another district in Gayo highland), which is about 900 to 1195 metres above sea level (Arfiansyah, 2020).

Thermal Comfort Based on Building Design

The influence of climate on building architecture can be seen from several aspects of the study, including can be seen in terms of architectural shapes and building materials used.

a. Building Shape

In building physics, factors from the dimensions and shapes of the building can affect the width of the shadow of the wind or leeward. The width of the wind shadow itself occurs in each form of a building both square shape or the mass shape of the building that does not have an angle.

b. Building Material

Solar radiation is the biggest heat contributor to a building. After a building, the sun's heat will be transmitted through the building sheath. This is due to the influence of the building facade system itself as a result of the ratio of the area of the wall sheath with the area of the material applied on the wall.

c. Opening Design

Openings are one of the important things in their influence of flowing air into the building room. For comfort, openings are useful in the air-cooling process and preventing the increase in air humidity, especially in the function of a residential house. The need for openings also depends on the number of users, user activities and functions supported by a building.

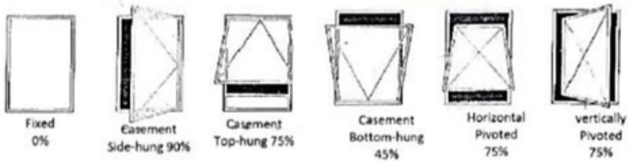


Figure 2. Type of Opening and Percentage of Air that can Enter the Building
Source: Becket (1974) in Latifah, N, L, et al. (2013)

The position and pattern of the building also influence the opening design, especially the application of the opening type. Different opening types will give a different steering angle in determining the direction of the movement of air in the space like the type in Figure 3. In this study, the type of opening used is the type of side-hug with the percentage of air that enters is 90 %.

d.Thermal Comfort based on Building Orientation

Building orientation is one of the factors that will determine the amount of solar radiation and the course of the airflow received by the building. The greater the area received by the solar radiation directly, the greater the heat that will be received by the building. Therefore, it is highly recommended that the north-south orientation is better if placed on the largest part of the building field, while the East-West orientation is better placed on a smaller side of the building.

For the flow of air itself, building orientation is also one of the factors that are affected by it. In this study, the type of orientation used is the orientation of the East-West and North-South.

RESEARCH METHOD

Location and Time of Research

This research was conducted in two Umah Pitu Ruang namely UPR1 and UPR2 located in Buntul Linge Village, Linge District, Central Aceh Regency, Aceh. The purpose of this location selection is because UPR in this village is the oldest one built since the beginning of King Linge I. This study was conducted based on field measurements conducted on August 4 and 5, 2022. Furthermore, the calculation was also carried out again by measuring temperature data Air (TA), relative humidity (RH) and wind speed (V) every 30 minutes starting from 8am to – 5 pm.

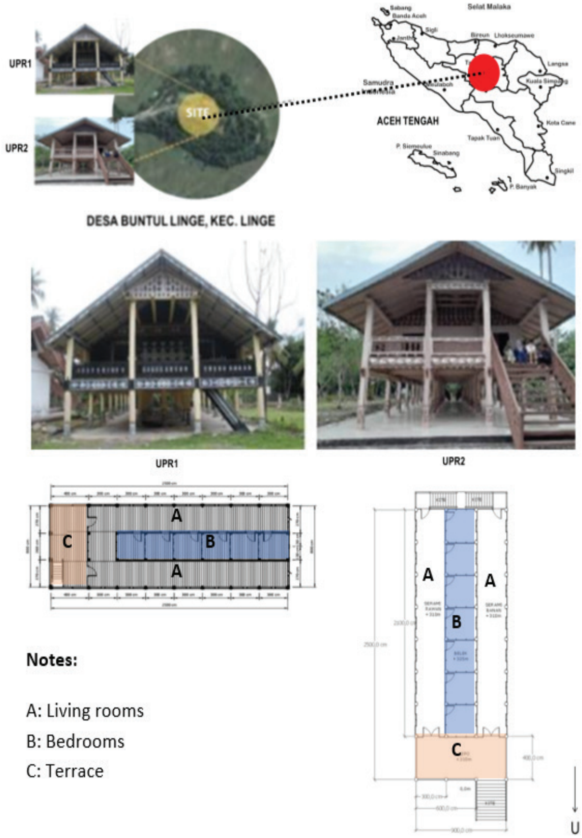


Figure 3. The location of Umah Pitu Ruang in Buntul Linge Village

Data Collection

In this study, the type of research used is a quantitative method approach. Quantitative methods are methods carried out by finding knowledge using data in the form of numbers as a tool to analyse information about what you want to know. Later, the quantitative method in this study was carried out by finding the results of measurements and observations on the object of research. Data collection is obtained from primary data sources and secondary data. Primary data is obtained through observation and survey directly to the field to get the thermal comfort variable which includes air temperature (TA), relative humidity (RH) and wind speed in the field (V). Meanwhile, secondary data. obtained through books, journals and other similar research.

The observation procedures carried out in this study were divided into two, namely:

a. Geometry measurement

This geometry measurement is intended to measure the dimensions of the building and the opening dimensions.

b. Identify material characteristics.

The process of identifying material is carried out to facilitate researchers in determining the reflectance of the material that can be used in the discussion of building design on the effect of building design.

Field Measurement

On the other hand, the thermal comfort measurement techniques conducted in this study consist of several aspects as follows:

a. Measuring instrument

Thermal comfort analysis is done by looking at the results of measured field data measured using the following tools:

1. Ellitech Temperature Humidity Data Logger

In this study, Ellitech Temperature Humidity Data Logger is used to measure air temperature (0C) and humidity (%) automatically placed at a point.

Figure 4. Ellitech

Figure 5. Hot Wire Anemometer

Source: Author

2. Hot Wire Anemometer

Hot wire anemometer is a tool used for measuring the wind speed (m/s) and air temperature (0C) and fluid direction. In this study, the Hot Wire Anemometer is used to measure air temperatures and humidity automatically placed at a point.

Measurement Time

The measurement was carried out for 2 days for the accuracy of the field data starting from 4th to 5th August 2022. On the 1st day, the data was taken every 30 minutes starting from 7 a.m. to 5 p.m. The measurements were made in the bedroom, living room, terrace and outdoors (Table 3.1) The two houses were naturally free running meaning that all windows were open. The measuring tools were located at 0.75 metres above the floor surface.

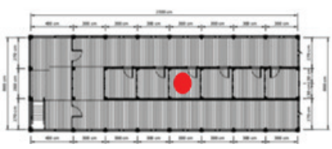
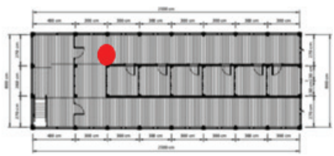
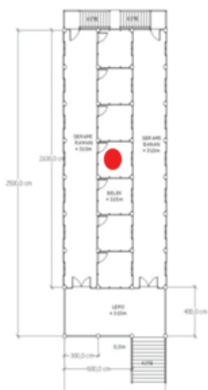
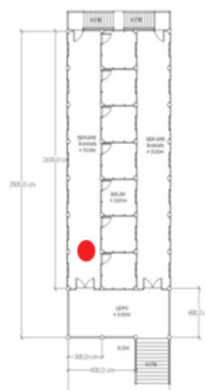
No	Initials	Bedroom	Livingroom
1	UPR1		
2	UPR2		

Figure 6. The Position of Measuring Tool in the Surveyed UPRs
Source: Author

RESULTS

Air Temperature

•Bedroom

There are no significant differences between the air temperatures (Ta) performance in the two houses either in the living room, bedroom or terraces (Figure 7, 8, and 9). However, UPR2 shows to have a slightly higher value of Ta compared with UPR1 which mostly occurred at 8.00 to 17.00. The highest and the lowest Ta were 330C and 210C respectively occurring in UPR2 and UPR1. This phenomenon indicates that orienting the windows to the east and west (UPR2) will give more time for the house to be radiated by the sun and thus become warmer.

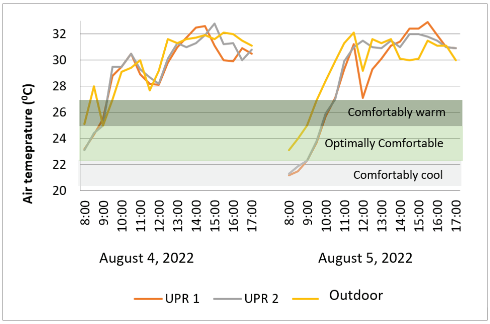


Figure 7. The Air Temperature in the Bedrooms

Source: Author

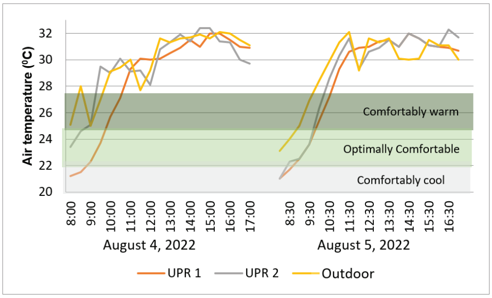


Figure 8. The Air Temperature in the Living Rooms

Source: Author

Figure 7, 8 and 9 indicate that during the day, the thermal performance is higher than the standard in SNI 03-6572-2001. While in the morning the results indicate that the temperature in this house is included in the threshold category.

●Outdoor space (lepo/terrace)

The average result of the measurement of air temperature carried out on the outer space for two days is 29.8 ºC on the first day and 29.3 ºC on the second day as stated in Table 6 and therefore based on SNI 03-6572-2001, the results indicate that the outer temperature in this house is included in the threshold category.

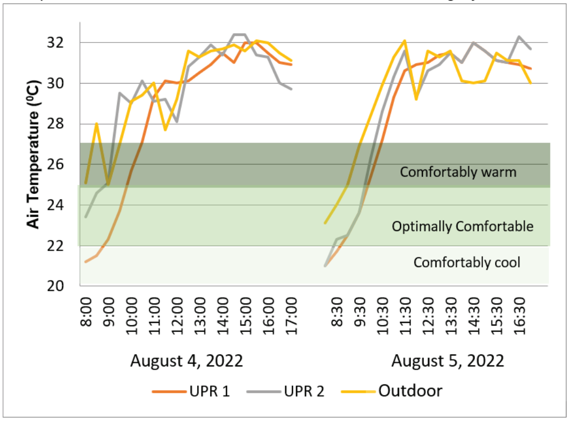


Figure 9. The Air Temperature in the Terraces

Source: Author

Air Humidity

●Bedroom

The average result of the measurement of relative humidity carried out in the living room and bedroom for two days are 62.79% and 58.64% respectively forUPR1 and UPR2 (Figure 10, and 11). UPR2 also has the higher value of Relative Humidity compared with UPR1.

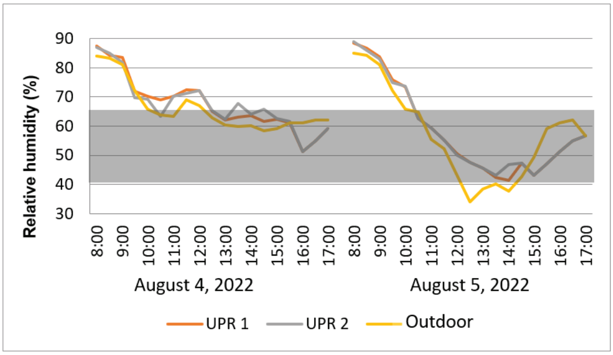


Figure 10. The Relative Humidity in the Bedrooms

Source: Author

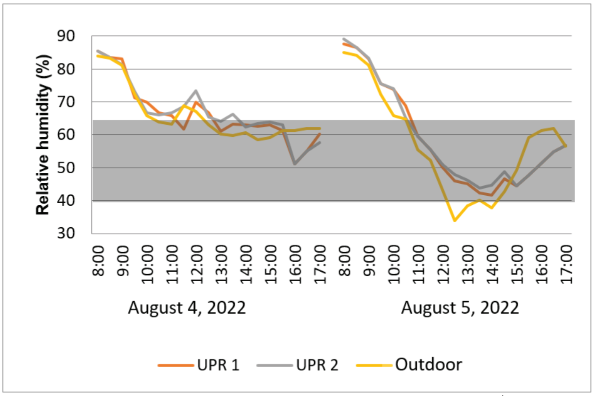


Figure 11. The Relative Humidity in the Bedrooms

Source: Author

Wind Speed

●Bedroom (booth)

The average measurement of wind speed measurements carried out in the room for two days is 0.1 m/s in UPR 1 and 0.1 m/s in UPR2 as in Table 8 below. Therefore, based on Table 2 of air velocity and coolness, the results indicate that the wind speed in this house is a good category and comfortable because it is still less than 0.25 m/s. Based on Figure 12 and 13, we indicate that the air speed in the two houses are slightly similar. However, UPR2 has one day i.e. on the 5th of August where the air speed is higher which is probably due to the air flowing from the openings straight to the measured area.

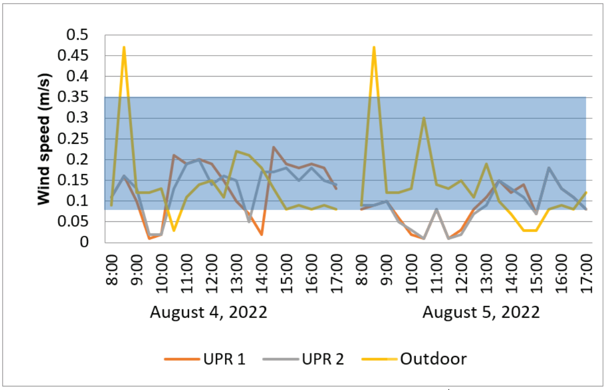


Figure 12. The Wind Speed in the Bedrooms

Source: Author

●Living room

The average result of the measurement of air humidity carried out in the living room for two days is 0.17 m/s in UPR 1 and 0.39 m/s in UPR2 as in Figure 13. Therefore, based on Table 2 of the air velocity limit and the coolness above, the results indicate that the wind density in UPR 1 is quite safe, but in UPR 2 wind speeds that enter exceed the comfortable category limit of 0.25 m/s.

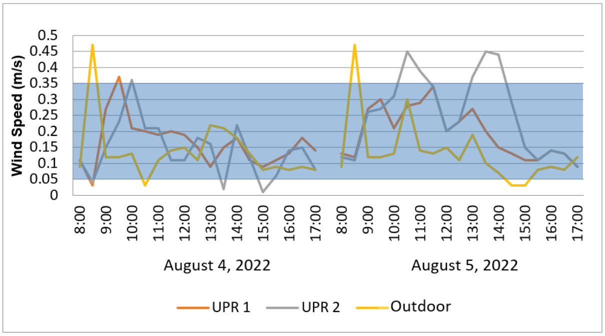


Figure 13. The Wind Speed in the Living Room (V)

Source: Author

●Outdoor space (lepo/terrace)

The average measurement of wind speed measurements carried out in the outer space for two days is 0.1 as stated in Figure 8. Therefore, based on SNI 03-6572-2001, the results indicate that the airspeed outside in this house is a cool category of comfortable and Optimal comfortable.

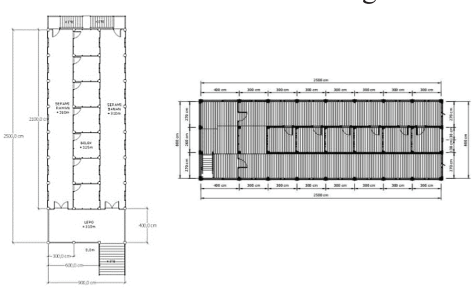
DISCUSSION

Analysis of Thermal Comfort Based on Building Design

Form of Building

In building physics, factors of the dimensions and shape of a building can affect the width of the wind shadow or leeward. In this case study, the shape of the building is classified as a rectangular shape as shown in Figure 14 below, which means a shape that has an angle so that it has a shadowing response to the wind. The height and width of the building will greatly affect the wind shading behind the building so as to make the wind shadow area 3 times the area of the Umah Pitu Ruang building itself.

If the wind blows from the west of the building, the wind will turn according to the slope of the roof of Umah Pitu Ruang, thus creating a wind shadow to the south of the building and reducing the building's thermal comfort. On the other hand, a building that has a rectangular shape will later be able to circulate the air that enters the building and can flow properly.



(a) (b)

Figure 14. Building Orientation UPR1 (a) dan UPR 2 (b)

Source: Author

Building Materials

The materials and walls of the two Umah Pitu Ruang buildings are both made of wood. Wood buildings are lightweight and easy to build. In comparison to other construction methods, such as steel framing, concrete and masonry, wood building systems have better thermal performance because wood is a natural insulation material (Sari, 2020; Cabral and Blanchet, 2021). Wood also has a lower thermal conductivity compared to concrete, steel-frame and masonry construction and is ideally suited to energy-efficient design. As a natural insulator, it provides some of the world's coldest climates with warm and comfortable dwellings (Cabral and Blanchet, 2021). Hence, the space inside the building still gets air circulation from the gaps in the wooden joints as shown in Figure 15. In addition, this wood material is better used in conducting heat during the day so that at night the conditions inside Umah Pitu Ruang remain warm because the Buntul Linge area is quite cold at night.

(a) (b)

Figure 15. Wood material applied to UPR1 (a) and UPR 2 (b) buildings Aperture Design

Source: Author

Aperture Design

Aperture is one of the important things in its influence on efforts to use wind in conditioning a building room (refer to Figure 16 and 17). In this study, the type of opening used is the easement side-hug type with the percentage of incoming air being 90%. This percentage also shows the fact from the results of measurements carried out where the average incoming wind speed is 0.1 m/s with a good and comfortable category.

(a) (b)

Figure 16. Type of Doors in UPR 1 (a) and UPR2 (b)

Source: Author

(a) (b)

Figure 17.Type of windows used on UPR1 (a) and UPR2 (b)

Source: Author

Thermal Comfort Based on Building Orientation

Building orientation is one of the factors that will determine the amount of solar radiation and the flow of air received by the building. Therefore, it is highly recommended that the North-South orientation is better if it is placed on the widest part of the building, while the East-West orientation is better placed on the smaller side of the building.

In this study, the orientation type used is East-West orientation at UPR1 and North-South orientation at UPR2. It can be seen in UPR1 that the widest part of the building area is placed on the North-South side, while the smaller side of the building is placed on the East-West part. The orientation of UPR1 looks good because the amount of radiation received is in accordance with the expected side of the building.

On the other hand, in UPR2 it can be seen that the orientation used is North-South orientation so that the smallest side of the building is in the North-South direction and the largest side of the building is in the East-West direction. This results in more sunlight and solar radiation received by buildings so that the air temperature rises. Therefore, in UPR2 the orientation applied is still not optimal but can be the best option for warming the interior (Rauzi et al, 2022).

Figure 18. Building Orientation of UPR1 and UPR2

Source: Author

CONCLUSION

Based on the thermal comfort analysis performed on the two Umah Pitu Ruang located in the village of Buntul Linge, the following conclusions can be drawn:

a. From the results of the analysis of thermal comfort, it is found that several environmental variables of thermal comfort still do not meet the aspects of thermal comforts, such as the variable air temperature. The two buildings both have air temperatures within the threshold category, which is around 31ºC.

b. From the results of the analysis it was found that the air humidity and wind speed in the two buildings met the criteria for thermal comfort aspects. Only in the living room UPR2, the measured wind speed exceeds the provisions. However, if it exceeds 2.5 m/s it could be in a good category depending on the dry air temperature that exists.

c. Viewed from the aspect of building design, in general, the two Umah

Pitu Ruang are quite good in terms of meeting the criteria for thermal comfort.

d. Viewed from the aspect of building orientation, UPR1 is good at meeting the thermal comfort criteria because it is in an East-West orientation. Whereas UPR2, which applies the North-South building orientation, is still considered less than optimal because the application of this orientation causes more irradiation and solar radiation received by the building on the side of the largest building, increasing air temperature inside the building.

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AUTHOR CONTRIBUTIONS

All authors contributed to the design of the research including the data observation, data analysis, and the write-up. All authors also have read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest

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