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Vernacular Passive Design With Natural Ventilation of Banjar Housing for Thermal Comfort

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Abstract

Thermal comfort research in Indonesia is known between 23 ºC and 25 ºC for dwelling buildings. As tropical weather is characterized by high humidity, high temperature, and intense solar insolation; therefore, traditional tropical housing is predominantly dependent on natural ventilation and passive cooling for thermal comfort. In the literature and practice, there is a gap in knowledge on traditional Banjar vernacular housing. Therefore, a thermal comfort field identification survey was conducted in the Balai Laki House one of the 11 types of traditional Banjar, which included information on the use of building space layout. The measurement results concluded that the category of thermal comfort is in the comfortably warm range, with the THI (Temperature Humidity Index) temperature range between 26,24 - 27,06 ºC . In addition, the upper threshold for comfortable warm conditions is indicated range of 27,29 - 31,28 ºC . The results revealed that the efficacy of traditional passive design techniques would not be sufficient to achieve thermal comfort in the predicted future climate scenario. For this reason, the authors suggested that the passive design techniques of Banjar vernacular housing need to be improved, with innovative solutions in order to cope with the changing climate.

Keywords : Banjar House, Balai Laki House, Thermal Comfort, Climate, Vernacular.

1. Introduction

In recent years, facing the risk of global warming and the depletion of fossil fuels, reduction in energy consumption along with sustainable development has been a priority for many countries. Particularly for rainforest countries including Indonesia, the household sector consumes about 27% and 32% of national total energy consumption and this figure may vary according to building type and cities location (Flores-Larsen and Filippín, 2021). Reducing energy use, especially energy used by occupants of buildings is an important issue in Indonesia. Research to discover alternative solutions through climate-responsive strategies without compromising human comfort is essential.

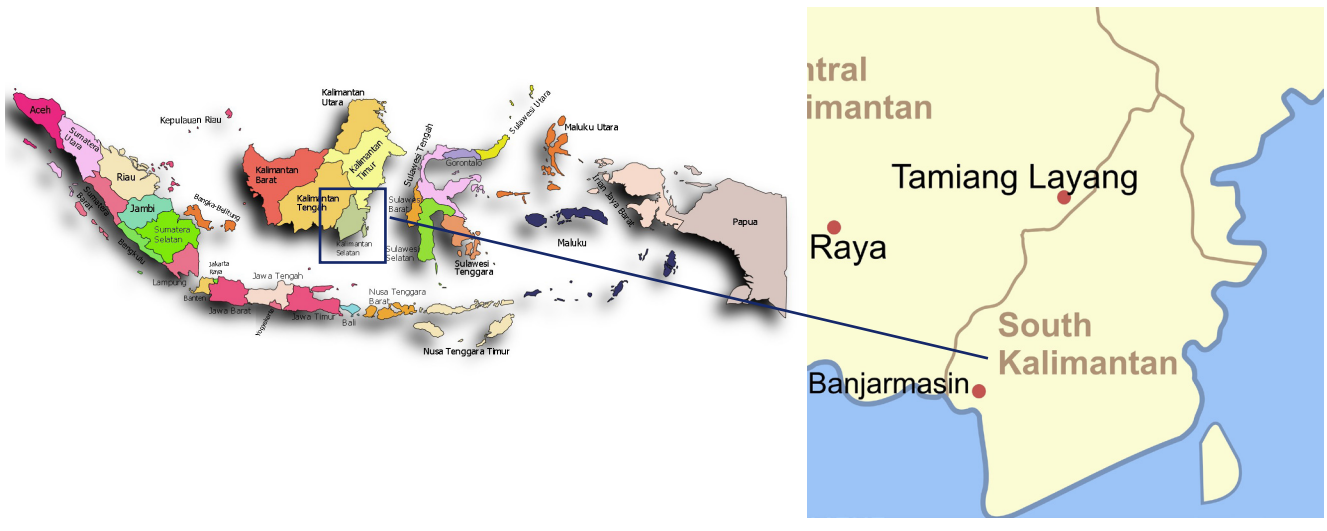
In Indonesia, many detailed studies have shown that Indonesian vernacular architecture is multiform and valuable (Laksmiyanti et al, 2023). In terms of energy consumption and material construction, vernacular architecture is widely recognised as a practical, effective and popular solution (Zune et al, 2020). Moreover, vernacular architecture results from long-term growth and is part of traditional popular culture; therefore, vernacular architecture is considered well-adapted to the natural and social conditions of a specific location in which it exists (Philokyprou and Michael, 2021). The approaches used in vernacular construction do not use special technical equipment, which makes them appropriate for contemporary dwelling building design. Analyzing such architectural vernacular can provide a proper method of achieving sustainability for the new generation of designers.

In Indonesia, Kalimantan Island is one of the major islands with a rainforest and humid regions, which has important vernacular architectural elements and plays a functional role in its urban development and sustainable architecture. Today, those remaining are very modest in scale and form, but the architectural and environmental lessons that they provide are still considerable (Karahan and Davardoust, 2020). Based on the fact that, by far, few studies have been performed on this issue, the present study was performed to search and discover the underlying climate-responsive strategies conceived in the vernacular architecture of the region addressing the concern of whether the vernacular architecture of Kalimantan Island can respond to the issue of sustainability appropriately. This research is a continuation of the research by Alkausar et al. (2019), was published previously so it uses the same execution methods and techniques.

2. Study Area

2.1 Banjarmasin Ecosystems

Kalimantan Island, the second largest island in Indonesia and the world's third largest island by a width of 743,330 km² located around the equator frequently named "Borneo" (Maloney et al, 2022). Kalimantan Island has its original inhabitants or ethnics which are spread in various areas, one of them is the Banjar ethnic community living in Banjarmasin on the South in Kalimantan Island (Ayudya and Rahman, 2019). The city consists of 45% rivers and canals flow throughout downtown. There are two seasons in Banjarmasin, it is the hot-



(A) Indonesia map (B) South Kalimantan Province map

Figure 1. Banjarmasin map (source: wikipedia)

Tabel 1. Average Daily Solar Radiation-Diffuse

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Insolation (KWH/M2)	2,3	3,3	4	4,7	5,5	7	7,5	7,7	6,3	6,5	6,8

-season and the wet season, which are annually changed by the ocean trade wind direction. By analyzing 2023 the statistical meteorological data of Banjarmasin station from early January to early December, most days experience weather conditions within ranges above the thermal comfort standard. Even on some days, the < 40% relative humidity and > 35 °C temperatures were recorded.

2.2 Climate Condition on Kalimantan Island

The above mentioned ecosystems display a significant effect on their shape and climate composition. Therefore, studying the climatic profile is of great significance while recognizing and offering appropriate plans in coordination with climate. Given its sea adjacency, very high air humidity and fluctuating rainfall occur in Banjarmasin. High humidity and sultry air on Banjarmasin are bearable for residents for a few months of the year. Table 1 shows the radiation conditions 2022 in Banjarmasin were obtained from the Meteorology, Climatology and Geophysics--Bureau (BMKG) website which also provides daily reports on all climatic information (rainfall, temperature, relative humidity, precipitation, number of rainy days and winds).

3. Housing Context in Banjarmasin

Indigenous Banjarmasin village settlement patterns are found along the banks of the Kuin rivers as a linear riverside village type (Setiadi and Kusliansjah, 2021), due to their livinghood focus on fishermen and sailors. Much of Banjar's carvings art and architectural patterns are tied to ancient Melayu-Islamic culture that can be traced to the Kalimantan's earliest known inhabitants. Many scholars believe that the first known habitual settlement in Banjarmasin was from an Arabian distinctive (Hidayat and Komarudin, 2019). Despite various ethnicities and cultures, 11 types of vernacular houses are found in Banjarmasin (Afdholy et al, 2019). The image shown in Figure 2 is from a online reference. In this paper, based on the field observations, common features used in--11 houses can be listed as described below, despite them being found in different locations.

The main houses are raised above the ground on a series of posts. An open space under the main house is either underused. Raised floors have several functions: to protect against flood, prevent moisture penetration from the wet ground, allow the house to be ventilated through cracks in the raised floor, and offset the radiated heat gain from the hot dry ground. Houses are either one or two-storey dwellings with a backyard and are rarely multi-storey. Family lifestyle patterns are usually reflected in the building size and building plan, which could serve either main or branch family models. The building layout is regulated by tradition, with a hierarchy based on resident's social status. Window locations are on either side of the building; some rooms are unlit, as most traditional livelihood activities are carried on outdoors. Ceilings are rarely built; therefore, gaps between the top of the walls and roofs allow natural light through the gable vents. One notable Banjarmasin-type feature of the Lanting house is the boat house type that can be used for fishing, as this house mainly lives in river regions.

4. Method

4.1 Scope of Work

The research specifically investigated Balai Laki House in Banjarmasin the Province of South Kalimantan. The house is on Jalan Kuin Selatan in Kuin Cerucuk Village, No. 17 RT. 01 RW. 01 . By applying three research stages, the evaluation studies aimed to compare the thermal performance of section Balai Laki House.The first stage of the study investigated the impacts of orientations and window-to-wall ratio on indoor air temperature for a typical model. The second stage of the study investigated the impacts of building sizes and roof arrangements on indoor air temperature. The third stage of the study investigated the impacts of various combinations of building components on indoor air temperature by comparing eight sections evaluated as listed in Figure 3. Indoor the Balai Laki House-



Figure 2. Common types of vernacular Banjarmasin architecture

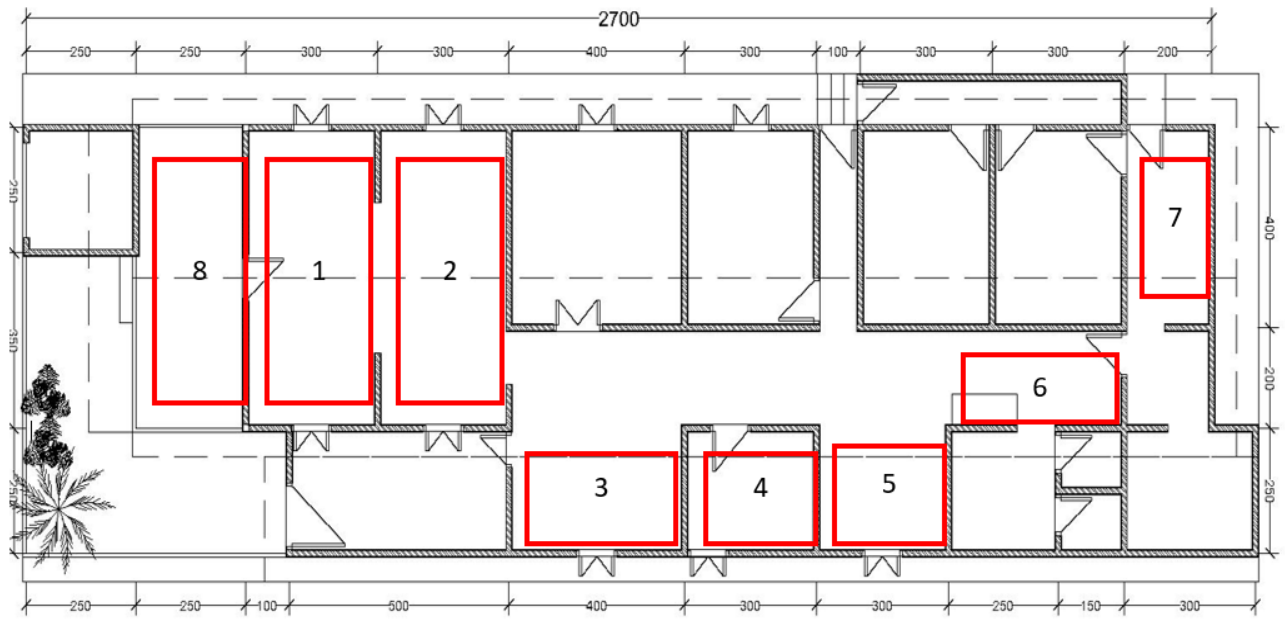


Figure 3. Spot location of Balai Laki House for measuring the physical environment
notes : (1) guest room ± 0,00 (large panampik); (2) living room ± 0,00 (large panampik); (3) left platform ± 0,00 (intermediate room); (4) room ± 0,00 (small panampik); (5) dining room ± 0,00 (inner panampik); (6) kitchen ± 0,00 (padapuran); (7) clothesline ± 0,00 (padapuran); (8) terrace ± 0,00 (palataran)

-there are 8 accessible rooms, consisting of 7 indoor rooms and 1 outdoor room. The room indoor includes a "large panampik" which is divided into 2 rooms: a living room (1) and a family room, (2) the "left pavilion" serves as an intermediate room, (3) the "small panampik" functions as a guest bedroom, (4) "panampik dalam" is the dining room,-(5) "padapuran" is divided into 2 spaces: the kitchen, (6) and the washing area, and (7) "palataran" is the front porch.

4.2 Data Analysis

The experiment consisted of capturing temperature and humidity datasets from a-

-thermometer every two hours with a duration of 10 hours, measurements were taken while standing at a height of approximately ± 1,6 m . The observed temperature time series varies greatly depending on the work schedule (from 07:00 to 17:00 local time WITA) during this time, temperature and humidity were continuously recorded with a WGBT Heat Stress Meter and Tridynamics to measure radiant temperature, air velocity, and air humidity.

4.3 Comfort Thermal Limits

The human body's thermoregulatory system is to maintain an essentially constant internal body temperature. As such, the effects of the immediate--thermal environment are mediated by the physics of heat and mass transfer between the (Sempionatto et al, 2019). It is assumed that people's sensations hot or cold are generally proportional to the magnitude responses measured in skin or due to sweating. A complex relationship was found between thermal sensation, preference, and acceptance. Subjects voting beyond the central categories have also accepted the thermal environment. These form the basis for the development of comfort thermal limits models. The existing literature is limited to the Indonesia contexts; however, according to all the aforementioned factors, it could be inferred that a similar range of thermal responses can be expected in Indonesia houses as found in Muhammad and Prianto's (2016) studies following; 1) 20,5 - 22,8 °C (Cool Comfortable); 2) 22,8 - 25,8 °C (Optimal Comfort); 3) 25,8 - 27,1 °C (Warm Comfortable); and > 27,1 °C can be categorized as the upper threshold for comfortable warmth.

4.4 Calculation of Thermal Heat Index (THI)

Temperature Humidity Index (THI) is a measure that can be used to assess comfort levels. This measure produces an index to determine the effect of hot conditions on human comfort that combines temperature and humidity (Metallido et al, 2020). The determination of THI or the comfort index can be calculated from the values of air temperature (°C) and humidity (RH) using the following equation (Kurnia et al, 2010) :

$$THI = 0{,}8\ Ta + \frac{(RH \times Ta)}{500}$$

Notes :
THI : Temperature Humidity Index
Ta : Temperature (°C)
RH : Air Humidity (%)

5. Result and Discussion

It is known that the Balai Laki Banjar House is ± 100 years old with the conditon of its typical ornaments thats all exist and a few modifications and additional appearances/rooms at the front of the house that function as commercial places. Based on the results of field surveys, the construction of the Banjar Balai Laki House is a stage, the type of house material used is ulin wood (iron wood), start from the found a on and wall structure, most of whichs all use ulin wood (iron wood). This house has a main/front door opening measuring L = ± 90 cm, T = ± 220 cm with ± 0,5 m high ventilation. The indoor temperature often reached much higher levels than the skin temperature, especially in the roof-exposed. In addition, the occupants also had very little access to shaded semi-open cooler spaces to 'adaptively move about' during the hot period.

There are 3 types of opening designs that lead out of the house, namely the first door opening with a size of 0,8 x 2,3 m, the second window opening with a size of 0,7 x 1,2 m and the third window opening with a size of 0,6 x 1,1m. Vegetation placement is only in the yard of the house towards the north on the left side in the form of banana trees and short titled plants. There is a shelter that surrounds the house in the form of a roof trench with a width of 0,5 meters made of zinc and an additonal trench on the right (east) side of the house with a width of 1 meter made of aluminium. The window opening conditon in the living room is only opened on the right side of the house because there is a small alley with a width of ± 2 meters. Especially in the area behind the clothesline, the wall is already made of zinc material.

The results of this paper showed that a model rooftop with a large window-to-wall ratio had a better result. Regarding the use of natural ventilation, there are five constraints: it does not work in hot air conditions; high natural ventilation is necessary for warm air conditions; moderate ventilation is appropriate in comfortable air condition; natural ventilation is not appropriate in humid air conditions; and minimal ventilation will help in the cool and humid air condition (Buonocore et al, 2020). Since highly humid air holds a higher temperature for a long time, a-

-complex outcome of combining high humidity and high air temperature in the tropics is the increase of warm air inside the space; therefore, higher natural ventilation throughout the day is necessary in order to remove the warm air inside. Nevertheless, further study is necessary to investigate the window size and rooftop's high requirement for natural ventilation throughout the year to change climate conditions. Overall, the study provided fundamental knowledge about the relationship between the Banjarmasin climates and-the Balai Laki House.

From the data results in table 2, the lowest and highest THI (Temperature Humidity Index) values and their differences can be found in the following table.

It is known that the lowest value of THI (Temperature Humidity Index) is 26,24 °C in the kitchen room (Padapuran) when the fifth measurement was taken at 15:00 - 17:00 . At the time of the measurement, the weather conditions were cloudy and the room was in the middle where it was-

Tabel 2. Identification Measurement in Balai Laki House

Location Analysis	Time Measurement	Air Temperature (Ta)	Radiant Temperature (°C)	Air Velocity (m/s)	Humidity (RH)	Weather Conditions	Analysis	
							Temperature Humidity Index (THI)	Type
Spot 1 Cheiling Height ± 3 m	07:00 - 09:00	28,8	30,5	0	70	Sunny	27,02	Warm Comfortable
	09:00 - 11:00	32	32,6	0,6	62,7	Sunny	29,61	Warm Comfortable
	11:00 - 13:00	33,5	34,2	0,4	59,9	Sunny	30,81	
	13:00 - 15:00	34	32,8	0,2	60,1	Sunny	31,28	Upper Threshold
	15:00 - 17:00	27,4	27,9	0	81,3	Overcast-Drizzle	26,37	Warm Comfortable
Spot 2 Cheiling Height ± 3 m	07:00 - 09:00	28,5	30,8	0	70,8	Sunny	26,79	Warm Comfortable
	09:00 - 11:00	31,2	32,8	0	64	Sunny	28,95	Warm Comfortable
	11:00 - 13:00	33,1	33,4	0,1	62,5	Sunny	30,61	
	13:00 - 15:00	33,5	32,9	0	60,1	Sunny	30,82	Upper Threshold
	15:00 - 17:00	27,7	28	0	80,3	Overcast-Drizzle	26,6	Warm Comfortable
Spot 3 Cheiling Height ± 3 m	07:00 - 09:00	28,7	29,6		75,6	Sunny	27,9	
	09:00 - 11:00	30,8	32,7		65	Sunny	28,64	Warm Comfortable
	11:00 - 13:00	32,2	32,9	0	64,1	Sunny	29,88	Upper Threshold
	13:00 - 15:00	33,1	32,9		65,7	Sunny	30,82	
	15:00 - 17:00	27,4	28,1		80,5	Overcast-Drizzle	26,33	Warm Comfortable
Spot 4 Cheiling Height ± 2,5 m	07:00 - 09:00	29	29,5		74,9	Sunny	27,54	
	09:00 - 11:00	30	32,1		67,2	Sunny	28,03	Warm Comfortable
	11:00 - 13:00	31,2	33,4	0	65,5	Sunny	29,04	Upper Threshold
	13:00 - 15:00	31,9	32,1		65,7	Sunny	29,71	
	15:00 - 17:00	27,5	28,1		79,1	Overcast-Drizzle	26,35	Warm Comfortable
Spot 5 Cheiling Height ± 3 m	07:00 - 09:00	28,6	29,8		73,2	Sunny	27,06	
	09:00 - 11:00	30,1	32,3		65,7	Sunny	28,03	Warm Comfortable
	11:00 - 13:00	30,8	33,7	0	64,1	Sunny	28,58	Upper Threshold
	13:00 - 15:00	31,9	32,1		64,8	Sunny	29,65	
	15:00 - 17:00	27,4	28		79,1	Overcast-Drizzle	26,25	Warm Comfortable
Spot 6 Cheiling Height ± 3 m	07:00 - 09:00	28,4	29,9		73,7	Sunny	26,9	
	09:00 - 11:00	30,3	32,1		64,8	Sunny	28,16	Warm Comfortable
	11:00 - 13:00	30,1	29,8	0	62,7	Sunny	27,85	Upper Threshold
	13:00 - 15:00	31,2	30,8		60,1	Sunny	28,71	
	15:00 - 17:00	27,4	28		79	Overcast-Drizzle	26,24	Warm Comfortable
Spot 7 Cheiling Height ± 2,5 m	07:00 - 09:00	28,3	29,9		73,7	Sunny	26,81	
	09:00 - 11:00	30,2	32,1		67,2	Sunny	28,21	Warm Comfortable
	11:00 - 13:00	31,2	31,1	0	65,7	Sunny	29,05	Upper Threshold
	13:00 - 15:00	32	32,9		62,7	Sunny	29,61	
	15:00 - 17:00	27,6	27,7		77,8	Overcast-Drizzle	26,37	Warm Comfortable
Spot 8 Cheiling Height ± 2,5 m	07:00 - 09:00	30,5	30,5		73	Sunny	28,87	
	09:00 - 11:00	31,9	30,8		68,3	Sunny	29,87	Warm Comfortable
	11:00 - 13:00	30,5	30,8	0	67,2	Sunny	28,49	Upper Threshold
	13:00 - 15:00	32	32,1		65,7	Sunny	29,8	
	15:00 - 17:00	27,5	28,1		80,4	Overcast-Drizzle	26,42	Warm Comfortable

-not directly exposed to the morning or afternoon sun. The highest value of THI (Temperature Humidity Index) is 31,28 ºC in the living room (panampik besar) when the fourth measurement was taken at 13:00 - 15:00 . At the time of the measurement hours the weather conditions were sunny, the state of the room's windows were open when thermal measurements were taken, there was no vegetation inside or outside the side of the room, there was only a road and a zinc-materialised house on the right side of the room Banjar Balai Laki House. This condition is the same as the results of research findings maulinda (2023), on the analysis of thermal comfort of traditional Acehnese homes that zinc material is an uncomfortable material as evidenced by the results of air temperature measurements and calculate the value of PMV and PPD show higher measurement results it is-because zinc material is difficult in releasing heat so that the temperature becomes high. It can be seen from this study that one of the real factors that cause changes in indoor temperature in addition to window opening conditions, materials, vegetation air humidity, or wind speed is weather changes.

The measurement results from 8 rooms of the Banjar Balai Laki House show an average difference in the measurement of THI (Temperature Humidity Index) value of 2,47 ºC to 4,91 ºC, the value is significant enough to change the condition of thermal comfort from comfortable warm threshold above into comfortable warm.

From Figure 4 (THI curve graph of the Balai Laki Room) it can be seen that the thermal comfort conditions of the "less comfortable/warm comfortable upper threshold" category in each room often occur in the fourth measurement,-

Table 3. Lowest, Highest and Difference THI (Temperature Humidity Index) Values

No	Name of The Measurement Room	The Lowest THI Value	The Highest THI Value	Difference in THI Value
1	Living room (panampik besar)	26,37 ºC	31,28 ºC	4,91 ºC
2	Family room (panampik besar)	26,60 ºC	30,82 ºC	4,22 ºC
3	Left pavilion (anjung kiri)	26,33 ºC	30,82 ºC	4,49 ºC
4	Guest bedroom (panampik kecil)	26,35 ºC	29,71 ºC	3,36 ºC
5	Dining room (panampik dalam)	26,25 ºC	29,65 ºC	3,40 ºC
6	Kitchen (padapuran)	26,24 ºC	28,71 ºC	2,47 ºC
7	Washing area (padapuran)	26,37 ºC	29,61 ºC	3,24 ºC
8	Terrace (palataran)	26,42 ºC	29,80 ºC	3,38 ºC

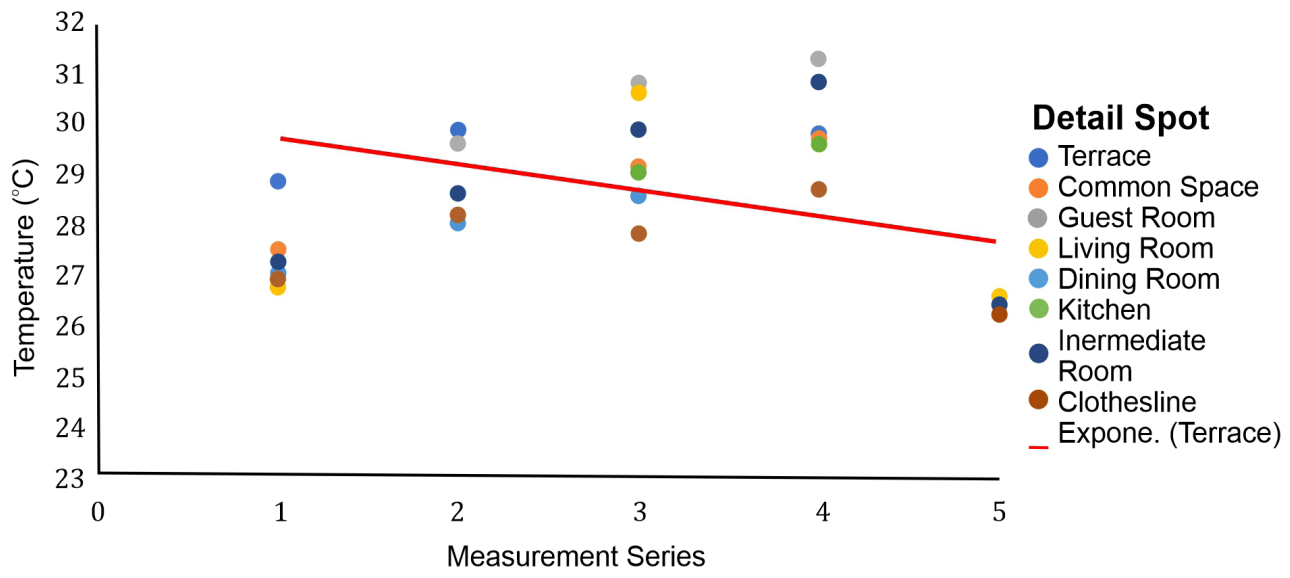


Figure 4. THI (Temperature Humidity Index) curve graph of Balai Laki Room

-around 13:00 - 15:00 local time, in sunny weather conditions. In contrast, the thermal comfort condition of the "comfortably warm" category in each room often occurs in the fifth measurement, around 15:00 - 17:00 local time, in cloudy-rainy weather conditions. Based on the results of THI (Temperature Humidity Index) calculations, it can be concluded that thermal comfort conditions are not only influenced by these four variables but also by the use of building materials such as roofs and window coverings made of sheet metal with aluminum frames. This is similar to the findings in a study by Rahman et al. (2021), which shows that the thermal conditions of buildings in Banjarmasin are higher than Saga, Japan. Moreover, the proportion of open windows and the proportion of open balcony doors vary with the time of the day. It can be observed that most of the windows and balcony doors remained closed during the most overheated period in midday when the outdoor temperatures were very high and humidity was at its lowest. As wind was blown from the hot exterior, opening windows and balcony doors during such hours, added only to the dry heat discomfort, convective and radiant gains.

6. Conclusion

Based on the results of measurements of the room Banjar House Balai Laki as much as 5 mes on the value of 4 parameters obtained can be concluded that the category of thermal comfort conditions included are comfortable warm and comfortable warm threshold above. Warm comfortable with a minimum THI (temperature humidity index) temperature value of 26,24 °C is on the fith measurement at 3 - 5 pm in the sixth room is padapuran room at a ceiling height of approximately 3 meters and a maximum comfortable warm category of 27,06 °C is on the first measurement at 7 - 9 am in the fith room is panampik room in (dining room) at a ceiling height of approximately 3 meters. As for the warm comfortable upper threshold with a minimum THI (Temperature Humidity Index) temperature value of 27,29 °C is in the first measurement at 7 - 9 pm in the third room, namely the left platform room (intermediate room) at a ceiling height of approximately 4 metres to the roof and the maximum warm comfortable upper threshold category of 31,28 °C is in the fourth measurement at 1 - 3 pm in the first room,-namely the large panampik room (living room) at a ceiling height of approximately 3 meters. From the results of the categorisa on, not only climatic thermal comfort that only plays a role in controlling the temperature value THI (Temperature Humidity Index), but there are other important roles that can affect, following ;

- Construction materials, the dominant type of material used in the construction of Banjar Balai Laki Houses is ulin wood (iron wood). Iron wood has good thermal insula on properties, which means that it has the ability to maintain the temperature inside the Banjar House better than concrete on materials. This can help keep the interior temperature of the house comfortable, especially in climates with large temperature fluctuations.
- Size and design the openings of the Balai Laki Banjar House are quite large. This shows the importance of air circula on and access to natural light in the house, which greatly affects the THI (Temperature Humidity Index) value.
- Vegetation and shelter: vegetation is only placed in the northern courtyard of the house on the left side, which consists of banana trees and short cropped plants. In addition, there are shelters around the house, including a 0,5 meters wide roof trellis made of zinc, and an additional trellis on the right (east) side of the house with a width of 1 meters made of alumunium. These shelters may have been used to protect the house from the elements.
- Window opening condition: the window opening in the living room is only opened on the right side of the house due to a small alley. This may affect the air circulation and natural lighting in the room.

Banjar Balai Laki Houses have unique characteristics in terms of construction materials, size of openings, vegetation, and shelter. The thermal comfort analysis also provides valuable insights into the environmental conditions within this house. These results can be used for improvement or redesign of the house to better meet the needs and preferences of the occupants. Conducting research activities related to thermal comfort conditions in climate spaces, required quantitative methods with a deductive paradigm that has been planned before carrying out data collection in the field, it is also recommended that during the process of measuring-

-thermal parameters required partners so that the process of activities can run smoothly.

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