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THERMAL PERFORMANCE OF VERNACULAR STILT HOUSE IN PALU CITY

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Abstract
The stilt house is one of vernacular architecture features in Indonesia. Several stilt vernacular houses persist until 70 to 100 years old in Palu City. Stilt house forms were proved to be adaptive to tropical climates. This research provides evidence of a thermally comfortable interior created by the vernacular stilt house of Palu City. The research was carried out in two stages: field measurement and thermal comfort value analysis, based on SNI 03-6572-2001 standards. Purposive sampling was used to determine the research sample for vernacular stilt houses. The selected stilt house is located on Anoa street No 57, North Tatura Ward, Palu City. Field measurement was performed to record the indoor and outdoor thermal condition of the sample house employing Hobo Onset U12-012 RH-Light data logger and Hobo H-22 microclimate station. The results show that the outdoor air temperature peak is 36.8°C with 45% humidity. Meanwhile, the indoor peak temperature on the 1st floor reached 32°C with 51% humidity. On the 2nd floor, there are five rooms with peak temperatures ranging from 29.5°C to 34.6°C with 53% to 64% humidity, indicating that each room has a different temperature performance. This condition is due to several parameters, such as ceiling height, roof shape, opening size, room layout, and room orientation. The result also showed that the indoor air temperature tends to be lower than the outdoor air temperature. Hence, it is indicated that the design strategies of the sample building are adaptive to the tropical warm and humid conditions of Palu.

Keywords: Thermal Performance, Vernacular, Stilt House

INTRODUCTION

Indonesia is an archipelagic country located in the tropical region, namely at 23.5°N - 23.5°S. So that Indonesia is exposed to sunlight and warmth all year round and has two seasons, namely the dry season and the rainy season. Characteristics of the tropical climate of the region in Palu City, Indonesia throughout the year, the air temperature in Palu City ranges between 23 °C – 36.5 °C and the temperature is never below 22°C, but sometimes the temperature can reach above 34°C at hot month. The cold month with the lowest temperature occurs in January while the highest temperature is in October. The average air temperature recorded at Mutiara Palu Meteorological Station reached 34.32 °C with air humidity ranging from 64.7 – 78.8 percent (https:palukota.go.id/keadaan-iklim/).

Comfortable temperatures for Indonesians are in the temperature range of 22.8°C - 25.8°C with humidity of 70%. Several studies on various ways to evaluate thermal comfort to find out whether the thermal environment is suitable for comfortable living. Certain design criteria for thermal comfort influence building design and control systems or building adaptation as in the research of Brager & de Dear, 2000; Halverson et al., (2014). One way to obtain thermal comfort is naturally through an architectural approach, namely designing buildings by considering orientation to the sun and wind direction, the use of architectural elements and building materials, as well as the use of landscape elements. In the architectural design process using a climate approach, there are four dominant variables, namely air temperature (T, °Celsius), relative humidity (RH), solar radiation (GT, °Celsius), prevailing wind speed (Vm/s).

The topical climate aspect is an important factor when constructing buildings in tropical areas, the physical influence on the building is very determining in the building's adaptive response to the local environment and climate. Because handling the local climate will produce thermal comfort in buildings and is in accordance with the local wisdom of the community (Hematang, Setyowati, & Hardiman, 2014). Processing the physical form of vernacular buildings is generally the result of trial and error that has been going on for a very long time, then imparting skills to the people. The process of constructing vernacular buildings is a skill that generally becomes a tradition in its own way carried out by certain communities locally and becomes knowledge that is passed down from generation to generation. Building buildings for vernacular communities is influenced by two factors, namely cultural and environmental factors. From a cultural perspective, this is the behavior of inhabiting the building, and the environment usually influences the construction system, building materials, building methods and the local climate. Vernacular buildings are the work of people who generally have local wisdom so that they always have a good thermal response to the building (Coch, 1998).

In building thermal studies, traditional architecture generally relies on passive design strategies to provide a comfortable building thermal environment. In tropical areas, efforts to achieve building thermal comfort are through natural ventilation for physiological cooling (Szokolay, 1997; Yang & Clements-Croome, 2020).

Culture always changes and shifts according to the conditions and developments of the times. Likewise with cultural products, some of them continue to survive unchanged, some also change, and some even disappear. As a cultural product, the Stage House is also the same, so it is possible that architectural adaptations occurred in the development of the Kaili tribe's stilt houses. Urban and cultural developments are starting to shift the existence of stilt houses, so it is necessary to document stilt houses because we might lose track of them if they are not conserved (Burhany, RB, Puteri, & Marwah, 2022). The original residents of Palu City, namely the Kaili tribe, inherited several types of architecture, namely Banua Mbaso/ Souraja, which is a special house for the nobility. The Kataba house is a residence used by the middle class of the nobility, meaning "Kataba" means a plank house consisting of all planks. The "Tinja Kanjai" house is a house for ordinary people, "Tinja Kanjai" means tie house (Zubaidi, 2009).

Many traditional houses in Indonesia have vernacular architectural values, including some folk houses in the form of stilt houses in Palu City. The stilt house located on Anoa Street in Palu city has very high vernacular architectural values, because this building was built by local people around 78 years ago. The building uses local materials, namely wood, and its design is based on the original local cultural identity so that it is very similar to traditional buildings in Central Sulawesi in general, especially in the use of ornaments, patterns and spatial layout, stair placement, structure and construction of buildings that are still very original and follow the culture and habits of the local people of Central Sulawesi.

According Holm (2006) states that Vernakular architecture tends to evolve over time to reflect the environmental, cultural and historical context in which it exists (Ibrahim, 2016).

Sutanto in (Gayatri & Purwanto, 2007), vernacular architecture is a transformation from homogeneous to heterogeneous cultures and seeks to present an image of traditional architectural reality as well as respect for "great" and "high" traditions.

Rapoport distinguishes between vernacular and traditional, where traditional Rapoport & Rapoport, (1969) is based on an agreement on a building model that is passed down through several generations without significant changes.

The research object is a vernacular stilt houses which is thought to use a tropical architecture approach in Palu City, at Anoa Street, North Tatura District, at 0°54'47.47"S, 119°53'19.94"E. This building is ± 77 years old in 2023. The shape and materials of this building are still the same original as when it was built, with a North-South building orientation and still maintains the initial shape of the building which depicts the characteristics of stilt

houses in Central Sulawesi, so This building was chosen as the object of this research, to prove the performance of vernacular buildings in tropical climates, especially in Palu City.

RESEARCH METHOD

Research desain and research stages

A positivistic research paradigm is used which emphasizes research quality with internal and external validity Groat & Wang, (2013) with a quantitative research approach. The research uses field research methods. The field research approach was chosen because this approach tends to involve in-depth observations in the field of an object, because this research uses direct measurements, including the dimensions of objects in the field, and the thermal response of buildings. Then problems and research questions on the object will be easily found through direct observation in the field.

Researh Sites

The research location is in Palu City at Anoa Street 1. The research used a purposive sampling method to select sample houses. The sample chosen was representative of the population, so it was determined that houses on stilts in Palu City were characterized by a tropical climate.

Research Stages

Research variables are used to analyze thermal performance in order to see the thermal performance of sample buildings. In this research, the variables that will be observed are the floor plan pattern, stage building construction, space pattern, room dimensions, ventilation design, and heat generation in the building (occupants, furniture and mechanical equipment) as independent variables. The climate variables analyzed are temperature, humidity and wind flow, as the dependent variable.

Measurement and observation techniques

Measurements were carried out to obtain data on the thermal conditions of the research samples (air temperature and humidity, as well as wind speed and direction) using the HOBO microclimate station, data logger and anemometer at intervals of 15 minutes and 2 minutes. Meanwhile, observation techniques are used for observation and photography. sketches/drawings and recording of sample houses such as dimensions of building elements, astronomical location, orientation and height of sample houses with the help of observation tables.

Measurement and observation techniques

Analysis of the thermal performance of sample houses was carried out by evaluating discomfort or degree-hours of discomfort. This analysis aims to determine the size of the hot and cold periods that occur within the comfortable temperature range determined based on the neutral temperature equation (Tn) by Auliciems (Szokolay, 2007).

Tn =17,6+ 0.31 x To Av (1)

Note: Tn= neutral temperature with range To.av = monthly average outside temperature.

The comfort range is analyzed by looking at the temperature conditions outside (To) and the temperature inside the building (Ti) against the comfort zone which has a range of +/- from the neutral temperature (Tn).

RESULT AND DISCUSSION

Existing Sample House

The sample is a stilt house located in a tropical climate area. Based on the Palu City government website, the air temperature in Palu City ranges from 23°C to 36.5°C, with the lowest temperature occurring in January while the highest temperature is in October. The average air temperature recorded at the Mutiara Palu Meteorological Station reached 34°C.32°C and air humidity ranged from 64.7% – 78.8%. During the year 2021, rainfall in Palu City was recorded between 4.5 mm to 112.5mm and the average solar radiation was 73.43%, the average wind speed reached 4.53 knots or around 2.1m/s the dominant wind direction from northwest.

The sample for this research is an original stilt house in Palu City which has a tropical climate. The sample is located on Anoa Street, has geographical conditions in the form of plains in the valley of Palu City which is the city center.

Figure 1. Photos and images of the front and side of the building in 2023

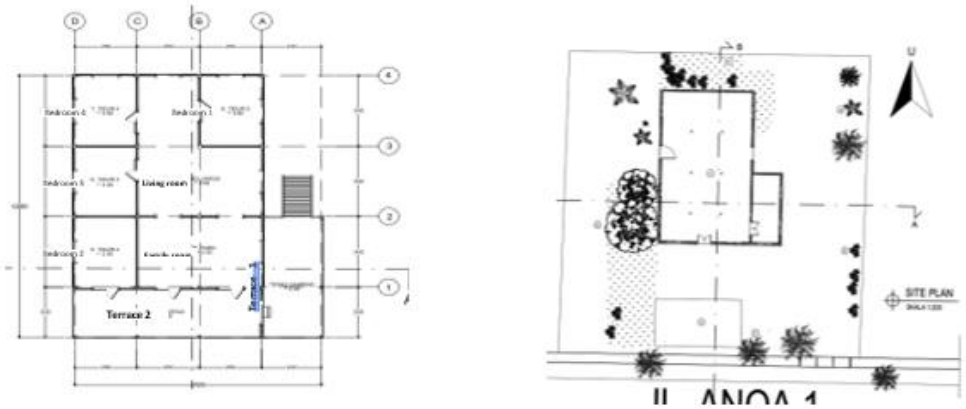

Figure 2. Research Object Stilt House

Second-floor room pattern of the house on stilts first floor of a sample house at at Anoa Street 1, Palu City, Central Sulawesi, Indonesia.



Figure 1. Point of measurement (Onset Hobo H21, Onset Hobo-004-2, Thermometer Manual, Thermometer Digital)

Vernacularity of Research Object

The buildings sampled in the study have several characteristics that are in accordance with vernacular architecture. The characteristics of vernacular architecture in buildings that affect thermal comfort are, building form, space pattern, location of openings, and use of materials.

The form of the building is in the form of a stage where the underbelly of the building is modified into a room used as a warehouse for crops (Copra) whose walls are bricks. The triangular roof cross section of the building is a gable roof made of wood construction with zinc roofing material, on the panapiri (triangular cross section of the roof) on the front and back sides there are openings in the form of windows made of wooden boards, these openings are where the air flows out and into the roof space and will reduce hot air in the roof space which has an impact on passive cooling in the spaces in the building. Because of the effort to stop the rate of heat radiation from the roof plane which is exposed directly to solar radiation during the day, this space is usually used as a storage area for valuable objects such as heirloom cloth and looms, where this object can withstand. The heat rate during the day and warm the room at night, because the object can absorb heat during the day and release heat at night (Andriansyah, 2021; Sidik & Fauzi, 2016).

This building has a spatial pattern like a traditional Central Sulawesi houses, namely Souraja or banua Mbaso. This spatial arrangement pattern is arranged based on the rules of customs and social life of the local Kaili tribe in Central Sulawesi which is organized into three parts of the function space as follows (Sidik & Fauzi, 2016) :

1. Terrace known by the local name Gandaria, which is the front room that functions as a terrace, this space is used only for men who function as a place to receive male guests and a place for discussion, in this building there are 2 rooms, namely terrace 1 which is located on the side of the building near the stairs and terrace 2 which is located in front of the living room.
2. The middle room is known by the local name Lonta Tatangana, this space is used for visiting, discussing, specifically for families or close relatives of the homeowner, in this building there are 2 rooms that represent this function, namely a special living room for close relatives and a family room which is used as a common room for residents of the house adjacent to 4 bedrooms.
3. The back room, known by the local name Lonta Rarana, is used as a kitchen and rest room for women, and has its own staircase access from the back of the house and also has direct access from the front, namely from the family room (note: at the time of this research, the kitchen/lonta rarana room was no longer there because it was damaged during the earthquake in 2018, but the main building was still intact and sturdy).

The orientation of the building towards the sun, the building faces south and extends from the north so that the openings of this building are generally located on the side of the building will receive direct radiation from the sun on the east and west sides of the building.

Materials generally use local materials, made from wood, such as walls, flooring, openings, ceilings, shutters, all using local wood materials with local construction systems.

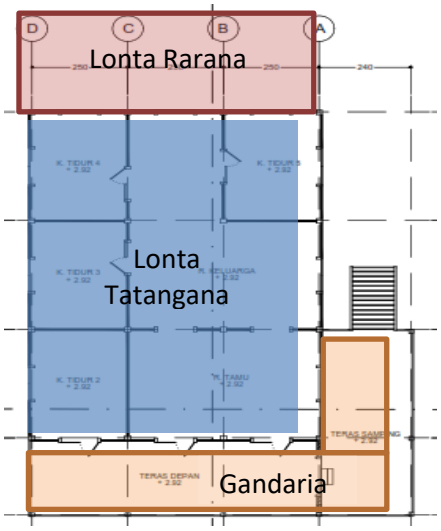

Figure 4. spatial planning based on the customs and culture of the Kaili community

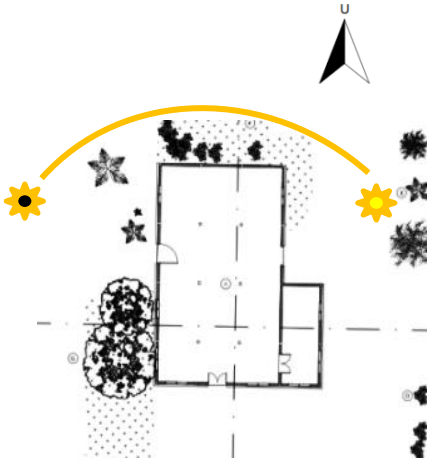

Figure 5. Orientation of the building towards the sun.

Figure 6. Panapiri shape of the research object building

Figure 7. Door and Window Models and Materials.

Figure 8. Gandaria / Veranda

Figure 9. Lonta Tatangana / living room

Thermal Analysis of the Building Environment (Microclimate)

Field measurements using a Hobo data logger and the measurement results show that the outside air temperature during the day is always above the thermal comfort zone for humid

tropical areas. The average temperature in the sample house is an average temperature ranging from 26-35ºC. The results of measurements from 27 June to 06 July 2022 were that the highest temperature occurred on 02 July 2022, namely 38.8ºC due to the weather at that time being sunny, and the lowest temperature was 29.7ºC the following day. Temperature fluctuations occur in the highest and lowest temperature ranges according to the measurement results, which are influenced by local climate conditions

The average external humidity in the samples was recorded from June 27 to July 2022. The measurement results show that the lowest humidity reached 43% and the highest humidity reached 86%. The results of these measurements show that the climate outside the stilt house building is a tropical Indonesian climate, with an average annual temperature generally around 23°C and can rise to 38°C in the "hot" season. In accordance with Lippsmiere's statement in the book Tropical Buildings, Indonesia's tropical climate has very high relative humidity (RH) (sometimes reaching 90%), quite high rainfall, and the average annual temperature is generally around 23°C and can rise to 38°C. °C in the "hot" season. has a wind speed ranging from 0.000-0.531 m/s with a wind direction ranging from 28.7-32.6 ø.

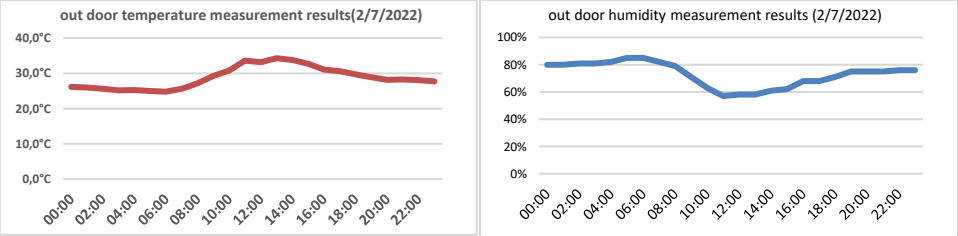

Figure 10. Outdoor temperature measurement graph for the sample

Thermal Analysis of Sample Buildings

Based on the data from temperature measurements in each room, it was found that the highest temperature in the environment around the building was 36.8°C and the humidity was 45%, while during the day at 1 p.m. with sunny weather conditions and the building was exposed directly to sunlight from the roof. Bedroom 1 is located on the east side of the building, the temperature is 34.6°C, humidity is 52%. Bedroom 2 is located on the west side of the building, the temperature is 32.1°C, humidity is 51%. The family room is located in the middle of the building, the temperature is 31°C, humidity is 64% and the living room is located in the middle of the building, the temperature is 95.5°C. whereas on the first floor (under the stilt house) the indoor temperature is 32°C humidity 64%. When the outdoor temperature is 36.8°C, bed room 1 has a temperature of 34.6°C, while bed room 2 has a temperature of 32.1°C, so there is a temperature difference of 2°C to 5°C between the outdoor and the indoor of the building, where the temperature. The indoor temperature is better than the outdoor temperature of the building, which proves that this stilt house is adaptive to the thermal environment. There is also a difference in temperature between each room in the building, which is influenced by the size of the room and the space pattern and position of the openings. This can be seen in the temperature measurement results of the family room and living room which has the best performance, because the room has quite wide openings and cross ventilation occurs and has the room is bigger than the other rooms. These conditions will affect the thermal comfort of the occupants of the house. At night, the temperature outdoor the building begins to decrease from 00 a.m. to 5 a.m., while the temperature indoor the building begins to decrease from 2 a.m. to 5 a.m., slowly reaching the lowest value of around 24°C to 26°C.

The results of temperature measurements in the family room (see graph in Figure 3), the temperature during the day ranges from 26.3°C to 29.5°C with an increase of 1°C every hour. This temperature increase is normal, even when the outdoor temperature reaches the highest

temperature, namely 36.8°C. at 1 p.m. and 2 p.m., the living room temperature was only 29.5°C and began to decline slowly an hour later.

This shows the thermal response and ability of this house on stilts to maintain a relatively stable rooms temperature. This situation is supported by a fairly good space (5m x 3m) and has an opening, namely a door from the terrace with a two-leaf model, and also has an opening, namely a door. from the direction of the living room, so that cross ventilation occurs which allows air to move freely. And having a large roof space with a wooden ceiling means that heat transfer from the ceiling can be reduced well.

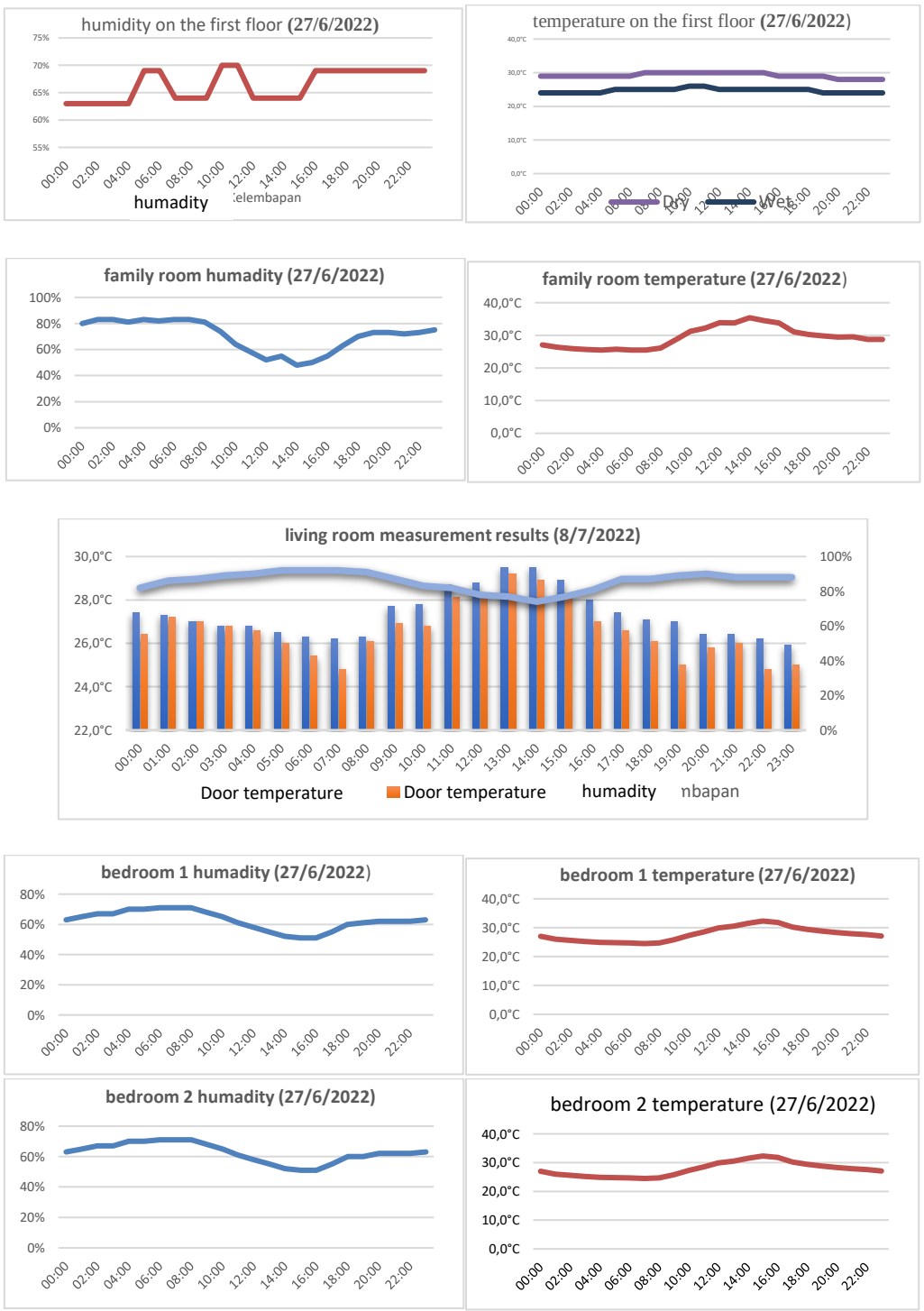

Figure 11 Graph of Sample in Door Thermal Measurement Results

Figure 12. Photo of the existing interior space in the sample building

Figure 13. sample house door and window shapes (wooden slatted windows and wooden doors)

Wind flow analysis in sample houses

Wind measurements were carried out for four days, based on the results of these measurements, it showed that the airflow that could enter several rooms was very minimal (ranging from 0.2m/s to 0.3m/s) and did not reach the standard (around 0.5m/s), especially in bad rooms. The opening position factor causes air to be trapped in the space because the opening is only on one side of the room. The opening position is not optimal in bedroom 1, resulting in the room retaining hot air longer than the other rooms. It is proven from the measurement results that bedroom 1 is the room that retains heat for the longest time, based on a comparison of temperature measurement data for all rooms.

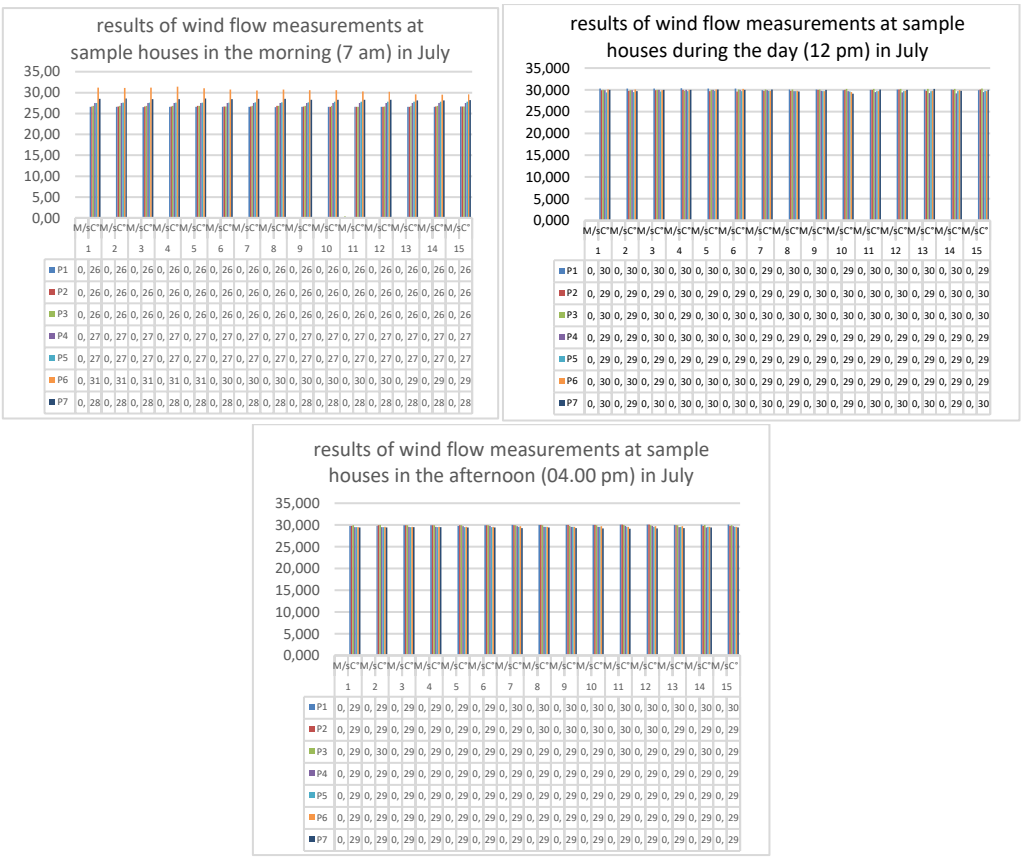

Figure 14. Graph of wind flow measurements at sample houses at three times (morning, afternoon and evening)

CONCLUSION

Buildings in areas with humid tropical climates often have difficulty meeting the standards required by Georg Lipsmeier's comfort zone. This is because the variables that influence thermal comfort are less supportive, including air temperature, relative humidity, solar radiation and indoor air speed.

Buildings in areas with humid tropical climate is often difficult to meet the standards required comfort zone by Georg Lipsmeier. This is because the variables that affect thermal comfort are less supportive, among others: air temperature tends to be warm throughout the year, the temperature difference between day and night is very little, relative humidity is quite high, high solar radiation, and air velocity is very low.

Efforts to achieve the desired thermal comfort need to be controlled, especially by reducing heat gain, orienting the building facing north-south, utilizing green open space, as well as using wood materials and bright colors in the building, arranging the ventilation system, providing curtains on parts of the building. directly exposed to solar radiation by designing solar shading devices to minimize radiant heat.

This stilt house has proven to be adaptive to the thermal environment of a humid tropical climate. The results of measuring temperature and air flow in buildings using hobo loggers show that family rooms and living rooms have the best thermal performance. This performance is supported by several factors, including space area, size and position of openings, shape of openings, building materials, and building orientation.

This building has local wisdom from the adaptation of vernacular architectural design values inherited from the traditional architecture of Central Sulawesi, in the form of original space patterns based on local culture and the use of local materials in buildings.

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