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Thermal investigation on the attics of buginese traditional houses in South Sulawesi

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Abstract. This study aims to investigate the thermal conditions of the attic of traditional Buginese houses in the climate of South Sulawesi. The analysis is carried out based on data surveyed from eight houses. The recorded data includes both attic internal weather data and the measured environmental weather starting at 08.00 to 16.00 Central Indonesia Time (CIT). Measurement results showed high temperature in the attics, ranging from 30.7 °C in the morning to 51.1 °C in the middle of the day. Relative humidity minimum of 17.3% at midday and the highest is 67.1% in the morning. The roofs temperature can reach 67.7 °C before midday. The temperature on the attic floor between 24.9 °C in the morning to 43.0 °C in the middle of the day. The difference in the surface temperature of the attic floor guesses to be an average of 1 °C higher than the ceiling surface. Environmental weather factors have the most dominant influence on attic thermal performance.

1. Introduction

Indonesia's climate conditions characterized by high solar radiation, high humidity, and cloudy skies, are the cause of high temperature in occupancy [1, 2]. Then, the residential roofs of traditional houses built in Indonesia's like traditional Buginese homes experiencing heat during the day. Heat transfer of solar radiation from the roof to the attic is popular among researcher most because of the mechanisms in the attic can be used to stabilize the room temperature below it [3-7].

The attic is the space or room at the top of a building, under the roof [8]. The attic is a space that experiences high heat loads so that it can affect the thermal space below it. Attic in a tropical climate will experience heat accumulation caused by direct solar radiation that hits the roof surface, so the roofing temperature rises and then transfers the heat to the attic space and radiates to the bottom of the attic so that it loads the room heat below [9]. Triangular roof attic with sloping small slope and small volume will heat up faster because the accumulation process occurs faster [10, 11].

Buginese traditional houses are similar to traditional houses in Malaysia, which also have a stage structure and have attic spaces formed from triangular roof shapes. Based on technical data from Air Vent [12], houses in Malaysia's climate are recorded during hot days with attics without ventilation, the temperature on the roof surface reaches 77 °C where the ambient temperature is 32 °C, the temperature on the attic floor can potentially equal 60 °C and subsequently produce an uncomfortable environment in the room just below the attic. This event is caused by a roof space that is not ventilated or lacking ventilation, and thick insulation that absorbs and stores a lot of heat. In addition, the attic room does not release heat at night to overcome the heat burden obtained during the day. Finally, this accumulation of heat causes the operation of buildings to be expensive [13].



The attic ventilation strategy is one technique to reduce heat buildup in the room. The benefits help control high energy consumption and improve the environment in the attic. This approach cannot completely stop the heat transfer mechanism from roof to attic [13]. Various ventilation strategies can influence attic air vents, in addition to the ventilation ratio and roof ventilation position, the thickness of roof insulation can be considered as a factor that influences attic airflow and temperature distribution. The results show that solar radiation has a significant impact on the amount and pattern of airflow in the attic [14]. The increased thickness of attic insulation results in a decrease in noisy during the rainy season but does not have a significant effect in the summer. In general, the thicker the attic insulation, the more favorable during the cooling period in the summer [15].

Numerous researchers have conducted studies of thermal on triangular attics to cool the room below the attic. These studies generally analyze strategies on differences of temperature in the attic with the environment for cooling of air with flowing up through in interior below the attic. Recent research addresses the development and verification of the Fraunhofer Attic Thermal Model (FATM). This FATM numerical simulation contributes to improving the implementation of the framework, the flexibility of changing frameworks is easily made, and introducing methods to create a modular framework to be implemented in a whole building simulation program. With the newly developed approach to determine the energy load in the attic space, the shape of the attic space and the construction system of new materials can be easily explored [4]. The solar chimney integrated with the triangular roof has been studied in the United States climate, to improve the performance of the photovoltaic arrays by reducing the heat absorbed by the panels, and enhance buoyant free cooling at night. A proposed method building energy modeling programs is zonal ESP-r, to evaluate the design and predict thermal dynamics in changing ambient conditions [16]. Tan and Wong [14], developed a regression model is based on the solar chimney's stack height, depth, and width to predict the interior airspeed. The recommendation is to maximize the width and height of the solar chimney. According to Al-Obaidi et al. [17], that a hybrid turbine ventilator can be combined with the chimney's stack effect to drain air out of the roof, due to the fact that this combination creates a constant airflow and provides a uniform distribution for extracting heat effectively. This study aims to identify the level of heat accumulation in many strategies using actual building models, with attics using turbines on the roof.

Thermal research on housing has also been carried out in Indonesia, such as Lapisa et al. [18]. The study aims to evaluate the effectiveness of passive cooling techniques in residential buildings in Padang city, namely reflective coatings on roofs, thermal insulation on ceilings and natural air circulation in attic zones and roofs to reduce energy requirements and increase thermal comfort in the building. The research method uses experimental and simulation software with TRNSYS-17 ©. Samodra and Yoon [19], examined the thermal properties of traditional Javanese houses on hot lowlands using a thermal comfort simulation method in the PMV standard using Echotect and Ansys Fluent software. The analysis was carried out on the shape of the roof, the building envelope, the combination of horizontal ventilation in the interior and vertical solar chimney which was set in an attic which ended at the top of the roof. Nugroho and Ahmad [20], presents alternative passive technology in the form of solar chimneys and green vertical landscapes that are integrated with houses in Malang to achieve indoor cooling. This strategy is considered to improve indoor thermal conditions significantly.

Based on the literature review, it is clear that research on the potential of passive cooling by modifying a triangular roof has resulted in the interest of researchers around the world. However, recent research has concentrated a lot on different temperate countries from the hot and humid climate. The hot and humid climate region has characteristics in terms of wind quantity and flows, air humidity, amount of solar radiation, solar sun paths, and cloud cover levels making the study of the triangular roof in the tropics significantly different. More specifically, in Indonesia, there is almost no research that concentrates on the study of measuring attic weather, so weather studies on attics need to be done. The purpose of this study was to report the thermal conditions on the attics of Buginese traditional houses in South Sulawesi.

2. Material and Metode

2.1 An Overview of Research Sites

South Sulawesi province is located between 0°12' and 8°0' South Latitude (SL) and between 116°48' - 122°36' East Longitude (EL). The area is belonging to the tropical equatorial fully humid climate [2, 21]. A common feature of the humid tropical climate is the relatively high air temperature, moderate to high radiation intensity, slight wind movement, and small heat exchange due to high humidity [1, 2]. Daily global solar radiation is relatively high, sky luminance for the sky covered entirely with thin clouds reaching more than 7000 candela/m², and the thick cloud covered 850 candela/m², clear sky ratio of 8%, intermediate sky 76% and overcast sky 16% [2, 22]. The most dominant climate impact in Indonesian buildings is the high intensity of solar radiation and high daily air temperatures, high humidity, and lack of wind flow [22-27].

2.2 Case Overview

There are eight traditional Buginese houses selected as case studies from four regencies consisting of two houses each in the Bone, Soppeng, Wajo and Sidrap regencies of South Sulawesi province. The recorded data includes both attic internal weather data and the measured environmental weather starting at 08.00 to 16.00 Central Indonesia Time (CIT), from April to October 2018. Automatic recording using a HOBO datalogger measuring device is set every 1 minute to measure temperature (°C) and relative humidity (%). Manually recording with a duration of 15 minutes, to measure the surface temperature of the roof and ceiling, using a K-type Thermocouple HT-9815 tool. This study did not take into account other room heat determinants such as wind motion and solar radiation.

The research method consists of two, namely: 1) measurement of attic internal weather and measurement of external weather or the external environment; 2) thermal measurement of the attic material surface.

Internal and external weather measurements. Measurement of the interior thermal environment of the attic space is carried out using the datalogger HOBO-1 tool (Figure 2b). The measuring instrument is placed in the attic room (see Figure 1). Weather measurement of the external environment is carried out using the data logger HOBO-2 with an external sensor (see Figure 2c), the device is placed under the home (see Figure 1). *Thermal measurements of material attics.* Thermal measurements of the attic material surface were carried out using the HT-9815 4 channel type K thermocouple, (Figure 2a). There are four cables attached to the center of the sloping roof surface (T1 and T2). One end of the cable attaches to the base of the attic (T3), and another is attached to the ceiling surface (T4), see the measurement point (Figure 1). The specifications of the instruments used in the data collection are displayed in Table 1.

Table 1. The specification of instruments used in the surveys.

No.	Instrument Name	Range	Accuracy	Resolution
1.	Thermocouple 4 Channel Type K HT-9815 o Temperature	-200 to 1372 °C	±1 °C (<-100 °C) ±2 °C (>-100 °C)	0.1 °C (<1000 °C) One °C (1000 °C)
2.	HOBO Temp/RH logger (UX100-011) o Air temperature o Relative humidity	-20 to +70 °C 5 to 95%	±0.21 °C ±2.5%	0.224 °C 0.05%
3.	HOBO Temp/RH/Light/External (U12-012) o Air temperature	-20 to +70 °C 5 to 95%	±0.21 °C ±2.5%	0.224 °C 0.05%

○Relative humidity	0.15 to 10 m/s	±0.05 m/s	NA
○Air velocity			

Note: NA = Not available.

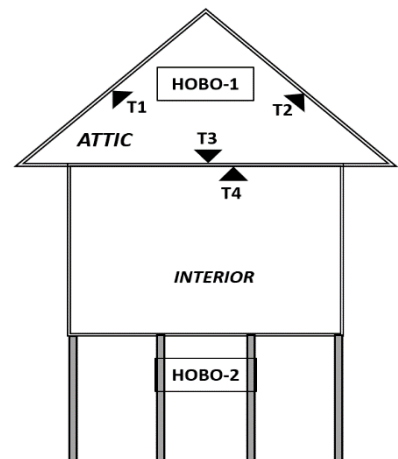


Figure 1. The measurement point

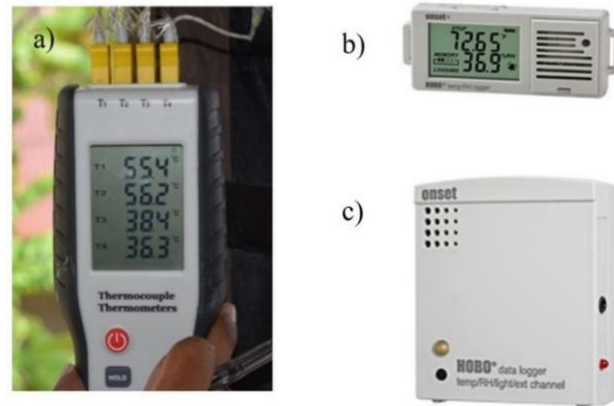


Figure 2. Instruments used (a) Thermocouple 4 Channel Type K HT-9815, Thermocouple temp; (b) Hobo-1, Hobo temp/Relative Humidity (RH); and (c) Hobo-2, Hobo temp/RH/Light/External logger

3. Results and Discussion

3.1 Internal and External Weather Measurements

Survey of internal and external weather data on the attic in traditional Buginese houses in South Sulawesi climate, carried out from April to October 2018. In general, weather conditions are sunny, although some cases experience cloudy or rainy weather in the afternoon.

The internal and external weather profiles can be seen in Figure 3, showing the relative temperature and humidity of eight cases of attics in traditional Buginese houses. The internal weather measurement results in the attic room temperature averaged 38.4 to 45.6 °C, the maximum temperature reaching 51.1 °C occurred around 10.00 to 13.00 CIT and the minimum temperature of 30.7 °C only occurred in the morning. Relative humidity averaged between 22.1 to 47.1%, with a maximum humidity of 67.1% and a minimum of 17.3%. When compared with the external weather, it is found that the average air temperature ranges from 30.1 to 34.7 °C, the maximum temperature reaching 36.7 °C occurs around 11.00 to 15.00 CIT and the minimum temperature of 26.1 °C only occurs in the morning. Relative humidity averaged between 38.3 to 70.2%, with a maximum humidity of 87.3% and a minimum of 30.0%.

Air temperature and humidity are thought to be highly influenced by outside weather factors. It can be seen from the graph the internal weather temperature of the attic to experience an increase of almost 1.5 times the temperature of the outside environment. Conversely, the relative humidity chart of the attics space shows a function that is inversely proportional to the temperature graph; if the temperature graph rises, then the reverse humidity graph decreases. The relative humidity of the attics can decrease to nearly 50% of the relative humidity of the external environment.

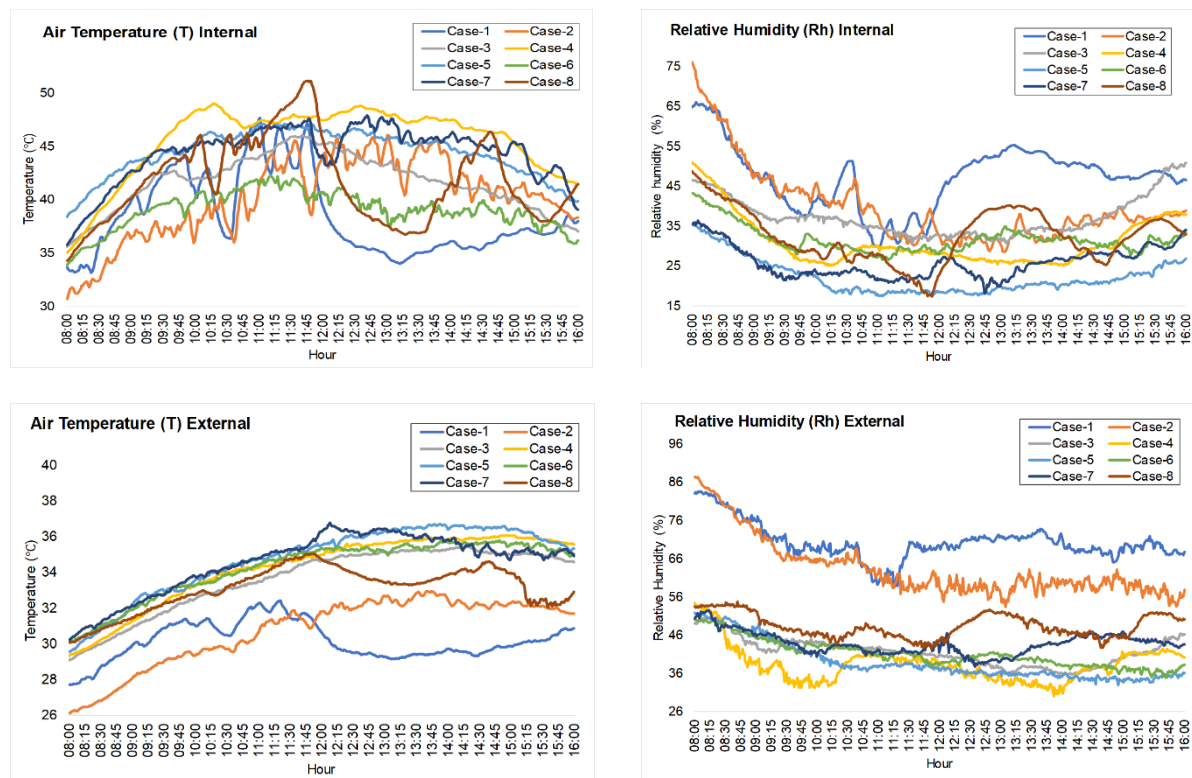


Figure 3. Temperature graph, internal relative humidity and external of attics
 T-internal = attic temperature, T-external = environment temperature, Rh-internal = attic relative humidity, and Rh-external = environment relative humidity

3.2 Thermal Measurements of Attics Material

Generally, the material used for the attic construction of eight cases of traditional Buginese houses in this study consisted of zinc roofing material, without coating with insulating material underneath. The material in the vertical wall covering the front and rear sides of the roof also uses zinc with minimal ventilation conditions. The base of the attic uses triplex or wooden boards.

The thermal profile of the roof surface, attic base, and ceiling surface can be seen (Figure 4). The results show that the average surface temperature of the roof ranges from 41.3 to 56.0 °C, the maximum temperature reaches 67.7 °C before midday, the minimum temperature of 30.4 °C occurs in the morning or if there is a change in weather such as rain or rain. The attic base temperature average of 30.9 to 39.9 °C, the maximum temperature reaches 43.0 °C occurs around 10.00 to 15.00 CIT, the minimum temperature reaches 24.9 °C, only occurs in the morning. The temperature of the lower side of the ceiling is an average of 30.5 to 38.8 °C; the maximum temperature reaches 42.5 °C occurs around 11.00 to 15.00 CIT, the minimum temperature reaches 25.7 °C, only occurs in the morning.

The roof of case-5 is the highest-temperature roof in this study, has experienced a peak of heat before midday that is 67.7 °C at 09.30 CIT with conditions environment temperature of 32.9 °C, when compared to the climate of homes in Malaysia [12, 13], the roof temperature of case-5 is still lower. The heat of the roof increases due to solar radiation will give heat penetration to the attic space which continues to accumulate, especially in attics with minimal ventilation; then heat is emitted to the bottom of the attic. This is what results in increasing the temperature of the room right below it. In this study found the difference in the attic base temperature using plywood material, it is estimated that the average is one °C higher than the ceiling surface temperature.

The measurement results for zinc roofs indicate that zinc material is easily subject to temperature changes due to changes in weather such as cloudy, rainy or strong winds to reduce roof surface temperature, because the properties of zinc roofs are a type of metal that has a high conductivity value,

easily absorbs heat at the same time easy to let go. The description of the value of the conductivity of materials used in buildings in Indonesia, such as wood and metal materials has been carried out by [28, 29].

Figure 4 shows the measurements in this study were carried out in fine weather. There are some cases of cloudy or even rain during the day or afternoon, as happened in cases 1, 2, and 8. Changes in environmental weather greatly affect the temperature of the zinc roof surface, which can drop dramatically due to wind, cloudy, or rainy weather. Roof temperature down for a long time can reduce attic temperatures, which can further reduce ceiling temperatures. Changes in ceiling surface temperature occur more slowly than roof changes.

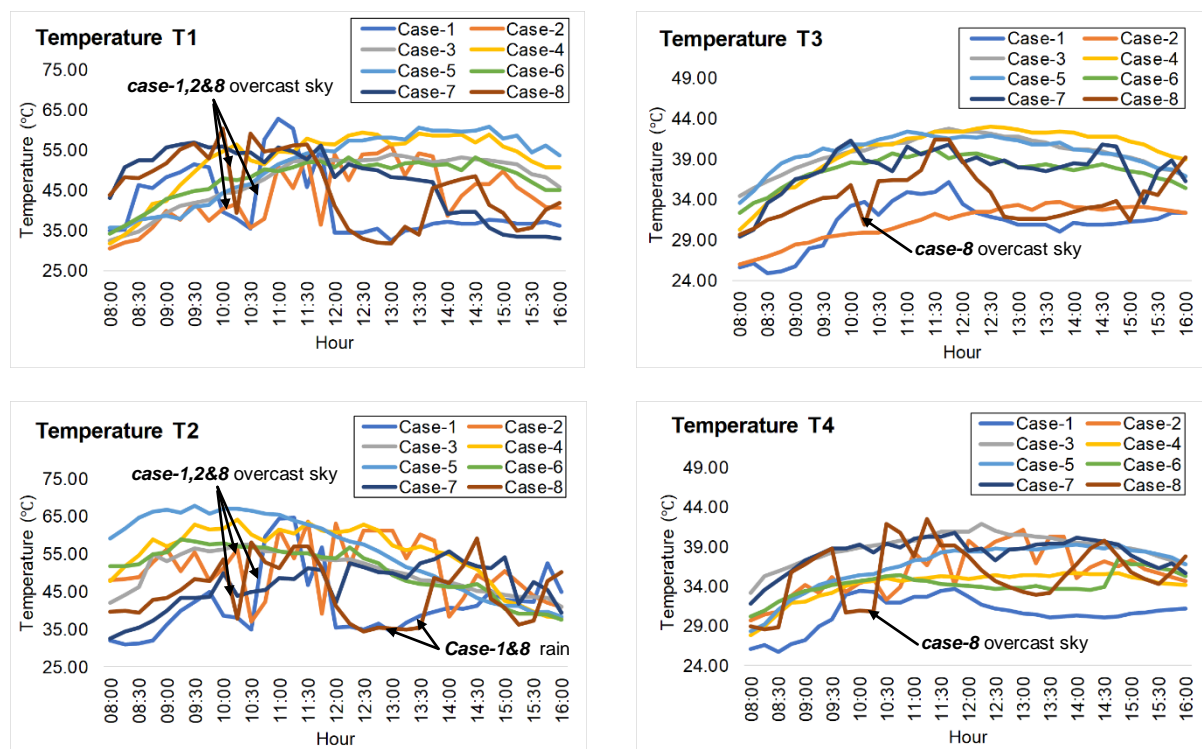


Figure 4. Graph the surface temperature of the attics material

T1 = left roof temperature, T2 = right roof temperature, T3 = attic base temperature, and T4 = ceiling temperature

The results of measurements of internal attic weather, measurements of environmental weather, the results of thermal measurements of roof and ceiling material surfaces have been carried out. In general, it can be concluded that the environment weather gives a dominant influence on the attic internal weather conditions compared to other factors in this study. These results support the results of previous studies [15].

The results of this research could be used as reference data for thermal studies of attics in the warm and humid tropical climate. However, this study has several limitations, especially the number of samples which is measured from surveys and the availability of equipment so that several variables such as solar radiation and wind data are not available. Subsequent research must use more meters and sensors that work simultaneously to collect data about the thermal environment with more samples.

4. Conclusion

The measurement thermal attic of the traditional Buginese house in South Sulawesi during the daytime the average temperature is above 38.4 °C; the air temperature is higher than 1.5 multiple the

environment temperature. The average relative humidity of the attic is in the range of 22.1 to 47.1%, the humidity of the attic air is almost 50% lower than the humidity of the environment. The roofs temperature can reach 67.7 °C before noon. Temperatures on the attic floor between 24.9 °C in the morning to 43.0 °C in the middle of the day. The difference in the surface temperature of the attic floor guesses to be an average of 1 °C higher than the ceiling surface.

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