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THERMAL COMFORT CONDITION IN AFFANDI MUSEUM YOGYAKARTA

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ABSTRACT

Thermal comfort is a basic human demand in interacting with space/architectural design. Determination of thermal comfort criteria can help the designer/architect in improving quality, function, and user thermal experience in an artificial environment. ISO 7730: 1994 standard states that the thermal sensation experienced by humans is the result of climate parameters (such as air temperature, radiation temperature, humidity, and wind speed) and human parameters (such as activity and clothing). These parameters were the focus of this study. The work program of this research collaboration was basically divided into 2 phases of activity, namely measuring and monitoring the conditions of thermal comfort in the Gallery 1 environment, Affandi Museum and providing recommendations for improvement of Gallery 1 thermal environment conditions. Primary data was taken from the indoor and outdoor measurement of air temperature, relative humidity and air velocity for 6 months. Physical architectural measurement of this study building and questionnaire methods followed the ASHRAE scale which was simplified to determine the level of thermal comfort, the scale of which was 2 (hot) to -2 (cold). The result of the measurement and analysis using a calculator based upon the ASHARE standard indicated that Gallery 1 of the Affandi Museum was in uncomfortable conditions. While the results of the questionnaire of 20 analyzes showed that at least 87,5% of respondents felt discomfort in Gallery 1, however, 60% of the respondent were still able to enjoy the collection and the atmosphere in gallery 1. The effective temperature index which provides 27,5-27,6°C and 66,7% RH as acceptable indoor environment in warm humid climate at Affandi Museum case.

Keywords:
Affandi Museum, Indoor Thermal Comfort, ASHRAE, Art Gallery

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1. Introduction

Thermal comfort is a comfortable situation or condition. Comfortable situations are often called comfortable areas, and some are referred to as quality ventilation. Comfortable conditions are an expression, enjoyment of staying, healthy conditions, and cool sensations. Cold sensation affects or is influenced by psycho-physical. Thermal comfort is influenced by natural factors and human factors. Natural factors include solar radiation, energy, environment, economy, building configuration, and air. Whereas the human factor is one's activity/behavior and adaptability. Thermal comfort affects the level of stress and the effectiveness of one's work. Thermal comfort is very personal. This is because it is influenced or influential on a person's psychology.

Thermal comfort in buildings can be created by paying attention to fresh air, comfortable areas, occupant behavior, attainment of comfort, and air quality outside the building. The Affandi Museum is an art museum designed by Affandi in 1962 to accommodate his collection of paintings. Affandi is a painter who never study in architecture school. This museum is public and is visited by many local and international tourists. Affandi Museum has its own attraction, in addition to the collection of paintings, also from the exterior and interior aspects. Gallery 1 is the first and main gallery. Gallery 1 collection such as oil paintings and awards received by Affandi. Some of Affandi's personal collection items are also stored here, such as a Colt Gallant car and a *onthel* bicycle.

At first, Affandi Museum has many openings but later in 2018 they decided to close it. As result, Gallery 1 has thermal comfort problem. This study aims to determine the thermal comfort conditions in Gallery 1 Affandi Museum.

Figure 1. Thermal Comfort Sensation
Source: www.affandi.org

As shown in Figure 1, gallery 1 is the main gallery and most visited place in Affandi Museum complex.

2. Literature Review

Thermal comfort is a physiological cooling which has a menaing as a sensation of comfort that is felt due to wind blowing against the skin. So the wind can blow the moisture or sweat and evaporate in the air (Satwiko, 2009).

The sensation of thermal comfort felt by humans is devided by psycho-physical scale of 7 points. The number is calculated from minus 3 to plus 3 which describes from cold to hot as shown in Figure 2.

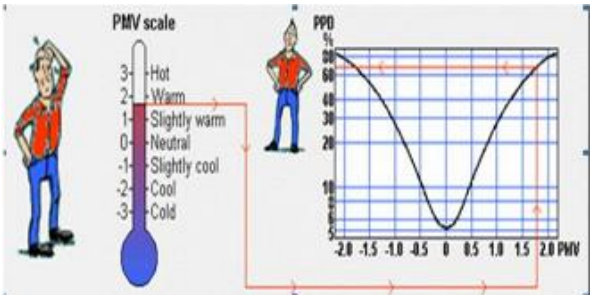

Figure 2. Thermal Comfort Sensation
Source: slideplayer.com/slide/4490690/

Thermal comfort variables are divided into physical comfort and non-physical comfort. Physical comfort factor is influenced by climate and non-physical comfort factors that influenced by human or user (Satwiko, 2009).

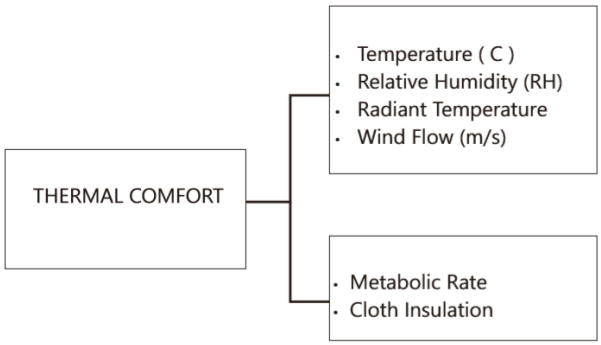

Figure 3. Thermal Comfort Variable
Source: Satwiko (2009) and ASHRAE (2011)

Satwiko (2009) said, areas in the *bioclimate chart* that show thermally comfortable air condition or temperature are called the comfort zone. Thermal comfort of temperature varies and cannot be represented by a single number. That's because of the comfort is influenced by many factors. However, based on research, thermal comfort in tropical humid region can be concluded to be in the range of 24°C < T< 26°C, 40% < RH < 60%, 0,6 m/s <V< 1,5 m/s, with single layer clothing used and relaxing activities. The existing limits can be calculated based on existing factors, the average temperature of tropical humid region is usually high and has 27-32 degrees Celsius average temperature. Tropical people can feel comfortable in range 24 degrees Celsius, but sub-tropical person can feel quite hot and uncomfortable in 24 degrees Celsius.

Thermal Comfort Standard

Standar Nasional Indonesia 2011

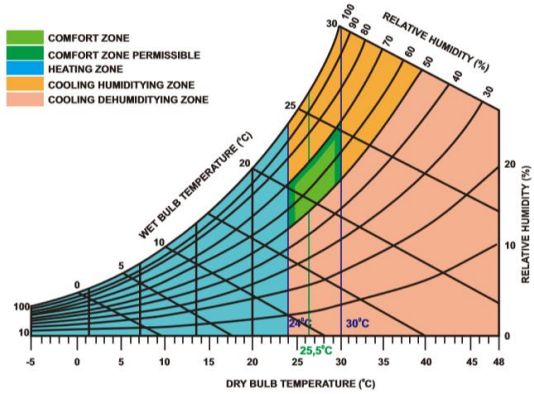

Figure 4. Thermal Comfort Standard SNI version
Source: Standar Nasional Indonesia 6390(2011)

Based on energy conservation standard SNI, the planning conditions of buildings that are in lowland or coastal areas with an average maximum air temperature around 34°C DB and 28°C WB (or average monthly temperature around 28°C) is determined that:

a. Working space: dry bulb temperature around 24°C- 27°C or 25,5°C ± 1,5°C, with relative humidity (RH) around 60% ± 5%.

b. Transit space (lobby, corridor): dry bulb temperature around 27°C - 30°C or 28,5°C ± 1,5°C, with relative humidity (RH) around 60% ± 10% (BSN, 2011).

ASHRAE 2010

According to ASHRAE Standard (2010), thermal comfort is a state of mind that expresses satisfaction with the surrounding thermal conditions. However, the conditions needed to obtain thermal comfort are not the same for everyone. There are six main factors that must be considered when determining thermal comfort, the six factors are as follows:

Table 1. ASHRAE Variable

No	Variable	Definition	Unit
1	Metabolic rate (metabolic rate)	rate of transformation of chemical energy into heat and mechanical work by metabolic activity in an organism, usually expressed in units of unit area of the total body surface	metric
2	Clothing insulation	is resistance to heat transfer caused by clothing suits	clo
3	Air temperature	temperature in the surrounding environment	Celcius
4	Radiant temperature	uniform surface temperature of an imaginary black enclosure, where the user will exchange the same amount of radiant heat as in the actual nonuniform space	Celcius
5	Air speed	the rate of movement of air at a point, regardless of its direction	m/s
6	Humidity	the ratio of the partial pressure of water vapor in the air with the saturation pressure of water vapor at the same temperature and total pressure.	%

Both of these standards, SNI and ASHRAE are thermal comfort standards that can be used in various studies. However, for this research, we will use the ASHRAE standard because the ASHRAE standard is more often used in various studies at research. In addition, a special software has been developed by Berkeley university that makes it easier to calculate thermal comfort (http://comfort.cbe.berkeley.edu/).

3. Research Method

3.1 Research Location

Figure 5. Affandi Museum
Source: Google Maps

Affandi Museum is located on Jalan Laksda Adisucipto No.167, Papringan, Caturtunggal, Depok, Sleman Regency, Special Region of Yogyakarta. Affandi Museum has an area of 3,500 square meters.

The main observational sites for research focus on gallery 1 or the main gallery at the Affandi Museum. The first gallery (314,6 m^2) was built in 1962 and officially opened in 1974. The original compound comprised of the first gallery and the house of Affandi. It was built gradually and designed by Affandi himself. Affandi's house as well as the first gallery took shape of banana leaves. Affandi chose the shape of banana leaves because of specific reason. Once there was chicken pox out breaks which no way to cure it at that time, no vaccine or medicine. His brothers and sisters including Affandi were also exposed to chicken pox. So his parents used the banana leaves to cover their body in order to cool down it and not to be swarmed by flies. That story inspired him to adopt its shape for the roofing of his house and museum. Retrospective works of Affandi are on display in this gallery, consist of sketches on papers; watercolor; pastel; and oil paintings on canvas, and a number of selected art masterpiece by Affandi. Also his statues made form clay and cement, and a reproduction of statue depicting Affandi and his daughter Kartika and his favourite car a 1976 Mitsubishi Gallant.

Figure 6. Affandi Museum Site Plan
Source: TU Wien (2015)

Table 2 Affandi Museum Room and Observation

No	Room Name	Notes
1	Gallery 1	Main Gallery, Art gallery (Oil Painting), Measurement and observation focused on gallery 1. Questionnaire main focused in gallery 1.
2	Gallery 2	Second gallery, art gallery (painting with ink), observation and questionnaire. Measurement only at 26 august 2019 for compare data.
3	Gallery 3	Third gallery, art gallery (painting), observation and questionnaire.

		Measurement only at 26 august 2019 for compare data.
4	Tower-gardu pandang	Tower, observation and questionnaire. Measurement only at 26 august 2019 for compare data.
5	Courtyard	Courtyard, observation and questionnaire. Measurement only at 26 august 2019 for compare data.
6	Steakhouse	Steakhouse, observation and questionnaire. Measurement only at 26 august 2019 for compare data.
7	Gallery 4	Gallery Gadjahwong located near Gadjah Wong river, it is more like a studio for kids or adult learn how to makes a painting. The observation and questionnaire taken here too. Measurement only at 26 august 2019 for compare data.
8	Entrance area	Ticketing corner, bench and parking zone for motorcycle and car, observation and questionnaire. Measurement only at 26 august 2019 for compare data.
9	Café Loteng	Cafe, The observation and questionnaire. Measurement only at 26 august 2019 for compare data.
10	Front of gallery	Small courtyard, observation and questionnaire. Measurement only at 26 august 2019 for compare data.

3.2 Field Measurement study

The study began with an observational survey conducted on August 26, 2019, to collect data on microclimatic conditions in the region as well as occupants' perceptions of data about these conditions. During this survey, the researchers took measurements of temperature, humidity and wind speed and conducted observations of behavior and simple interviews from visitors. Previously, measurement or retrieval of microclimate data (air temperature, humidity and wind speed) has been carried out continuously by Danube University Krems from Austria in collaboration with UGM since January 2019 until planned for completion in January 2020. Measurement data was taken per 5 minutes with measurement point as shown in figure 1. In this study, the data had been collected and processed data from January until July 2019.

Figure 7. Multimeter Position

Source: Author (2019)

The measuring instrument used in this study was a multimeter mounted on the interior and exterior walls in gallery 1. This multimeter measured temperature, RH, noise, and wind speed. The measurements were recorded every 5 minutes. While interior air velocity measurements were carried out at 4 points using an anemometer.

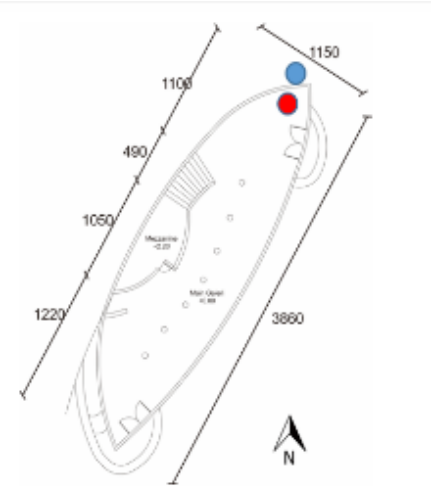

Figure 8. Multimeter Position, Blue is Outdoor and Red is Indoor

Source: Author (2019)

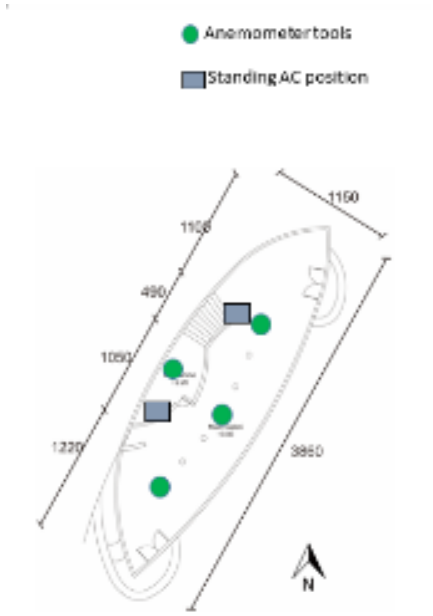

Figure 9. Anemometer Position

Source: Author (2019)

3.3 Questionnaire Method

The questionnaire method aimed to record the thermal comfort felt by the occupants and the contents of the questionnaire mainly involved indoor thermal sensation, as shown in Figure 10. The indoor thermal conditions were assessed by selecting the thermal sensations, humidity sensations, wind flow, and design sensations using the evaluation scale listed in Table 3.

The respondents were 20 UGM students, 7 males, and 13 females. All of the respondents did the same activity

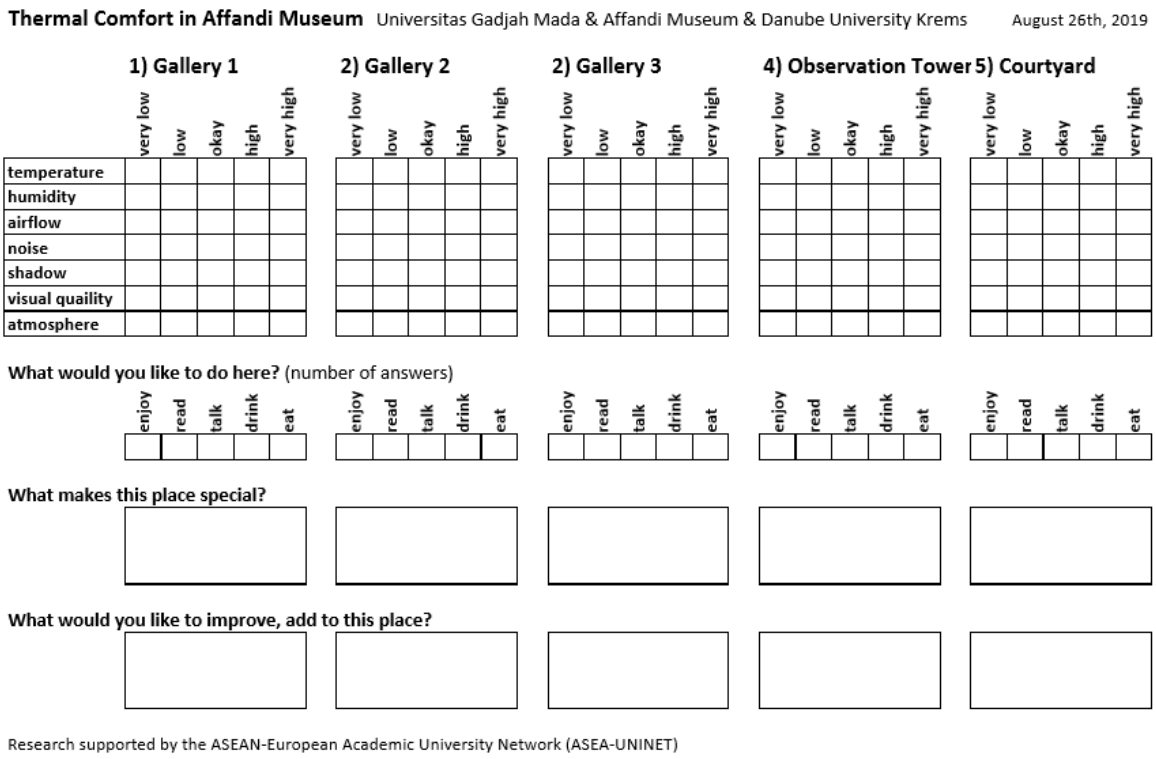

Figure 10. Questionnaire Sheet

Source: Author (2019)

(standing, relaxing, and enjoying the museum) and wore standard summer clothing (shirt, jeans, trousers, and veil for some females). All respondents were between 23-30 years old.

Table 3. Index Scale of Self Evaluation

Scale	Note	Temperature	Rh	Wind Speed
2	Very low	Cold	dry	Stagnant
1	Low	Slightly cool	Slightly dry	Gently breeze
0	Okay	Neutral	Neutral	Neutral
-1	High	Slightly warm	Slightly humid	Slightly draught
-2	Very high	Hot	Humid	Draught

In addition to questions about thermal comfort, the questionnaire also asked users perceptions of Gallery 1.

- What would you like to do here?
- What makes this place special?

The questionnaire held on August 26, 2019 at 11-13.00 in sunny weather condition. All the respondents have to fill all the question as shown on figure

4. Results and Discussions

4.1 Classification of Data

The stages of analysis for this research object are as follows:

Classification of temperature data and indoor RH during the day and night, so that the following data were obtained: The average temperature is higher in the daytime at 28,78°C, the slight difference at night is 287°C. The highest daytime temperature in May is 29,52°C, and at night 29,46°C. The temperature at the lowest daytime in July is 27,91°C and at night 27,77°C. This is evident from chart 1. Relative humidity is higher at night with an average of 66,55%, while during the day an average of 28,7%. The highest RH was found in January during the day which is 70,85%, and at night 71,82%. The lowest RH is in July during the daytime which is 60,11% and the lowest at night is 60,17%. This can be seen more clearly in Figure 11 and 12.

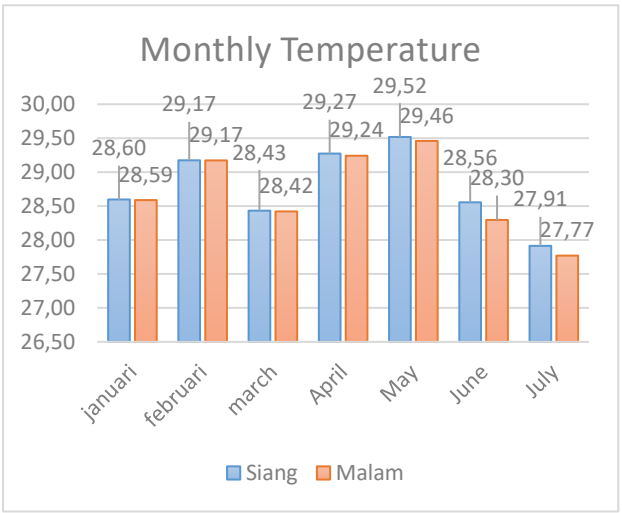

Figure 11. Monthly Indoor Temperature (Celsius)

Source: Field Measurement (2019)

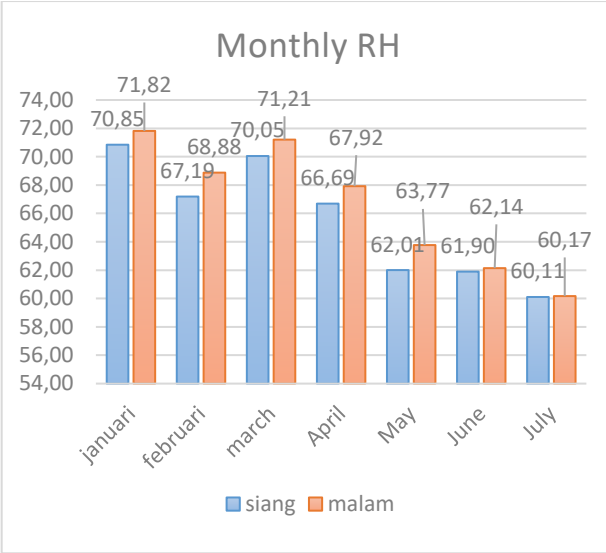

Figure 12. Monthly Indoor RH (%)
Source: Field Measurement (2019)

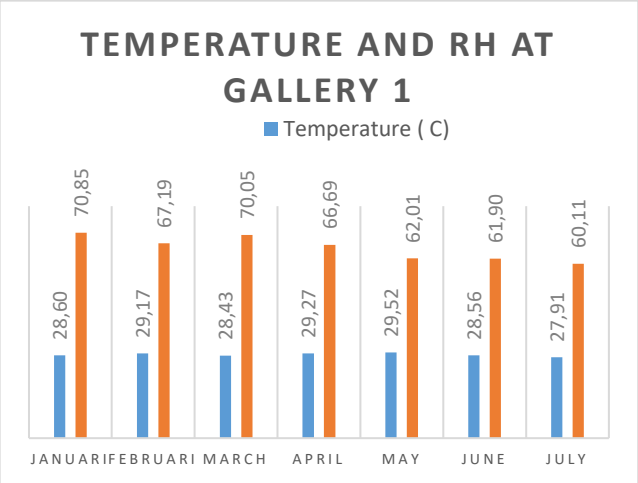

Figure 13. Average Monthly Indoor Temperature (˚C) and RH (%)
Source: Field Measurement (2019)

Classification of temperature data and indoor relative humidity (RH) during the day, so the following data were obtained: The average temperature in the daytime was 28,78°C. The highest daytime temperature in May was 29,52°C and the lowest daytime in July was 27,91°C. Relative Humidity during the day average of 65,54%. The highest RH was found in January at 70,85%, and the lowest RH was in July at 60,11%. This can be seen more obvious in Figure 13.

Analysis based on the 2010 ASHRAE standard

The measurement data above is the basic data to be input into the ASHRAE CBE calculator that has been developed by Berkeley. The result of this calculator is a psychometric chat. The psychometric chart is a graphical display of air thermodynamic properties including temperature, humidity, enthalpy, moisture content, and specific volume. In this chart, it can be seen directly the relationship between various air parameters quickly and precisely, both related to the physical properties of the air and its thermal properties.

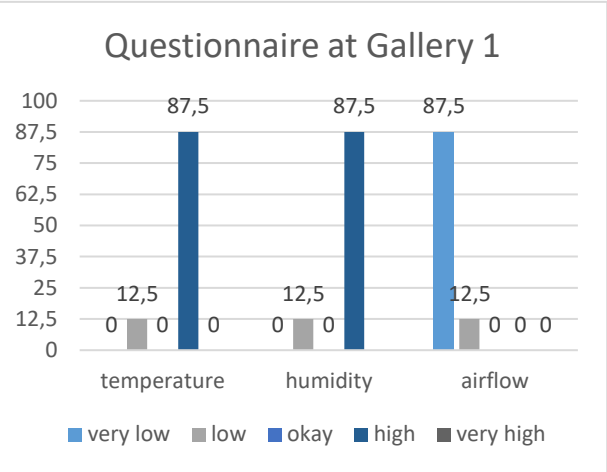

Figure 14. Questionnaire Result
Source: Author (2019)

The data was input monthly to see the level of convenience distribution per month. From the results of calculations according to the ASHRAE standard in the daytime condition in gallery 1 of the Affandi Museum turned out to be uncomfortable. This can be seen more clearly in Figure 13.

The thermal comfort position on the psychometric chart in Figure 14 can be seen in the blue area. While the thermal comfort distribution points of the building can be seen at monthly colorful points. The position of the monthly dots is completely outside the blue area, indicating the thermal comfort conditions are not achieved.

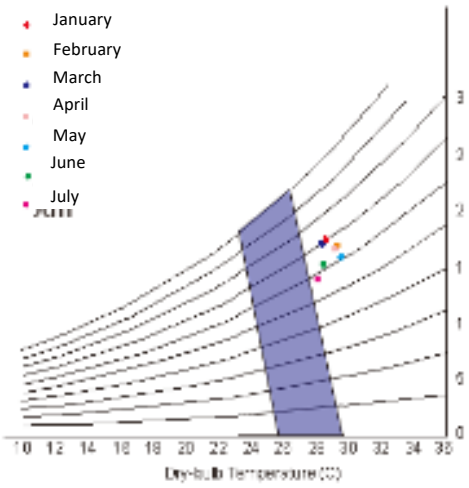

Figure 15. ASHRAE calculation- Monthly Average
Source: http://comfort.cbe.berkeley.edu

Table 4. Measurement Input When Questionnaire Held on August 26, 2019

Temperature	29,55	C
RH	67,1	%
Wind Speed	0,03	m/s

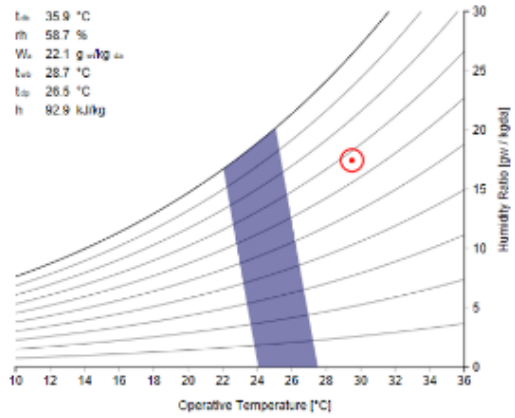

Figure 16. ASHRAE calculation in August 26, 2019
Source: http://comfort.cbe.berkeley.edu

Questionnaire Result

Questionnaire results at gallery 1 were 12,5% of the respondent felt low temperatures, 87,5% felt high temperatures, 12,5% respondent felt low RH and 87,5% felt high RH. Meanwhile, 87,5% of the respondents felt low airflow and 12,5% felt fine. All respondents wore the same type of dress and did the same activities, stand, relaxed and enjoyed the artwork. The actual measurement at the gallery 1 was 29,55°C, 67,1% RH and 0,03 m/s.

Based on ASHRAE standard high RH & temperature while low airflow means the situation is not comfortable. The measurement result at the point of the questionnaire takes place. Based on ASHRAE psychometric chart the thermal comfort can be seen as Figure 15.

The thermal comfort position on the psychometric chart in Figure 15 can be seen in the blue area and the position of the dot is outside the blue area, indicating the thermal comfort conditions are not achieved in gallery 1.

Table 5. Physical Setting on Gallery 1

Physical setting	Gallery 1
Ceiling	+ 7-8-meter, special structure, special fabric and skylight
Opening/ Natural ventilation	No
River position	Bit Far
Number of floors	1 and mezzanine
Void	yes
Collection	Affandi's personal car, the award from government, sculpture and oil painting

Although thermal comfort was not achieved in gallery 1, the respondents voted 60% enjoyed the situation, 30% talked and 10% drank at gallery 1. Most of the visitors at gallery 1 thought about the stage/mezzanine, the use of fabric in the skylight, arrangement or room layout, roof structure, light condition for art and the atmosphere makes the gallery 1 special. Many visitors wanted to improve the thermal conditions because gallery 1 feels too hot, low airflow and very humid. Some of the visitors also thought about lighting, space and wall paint.

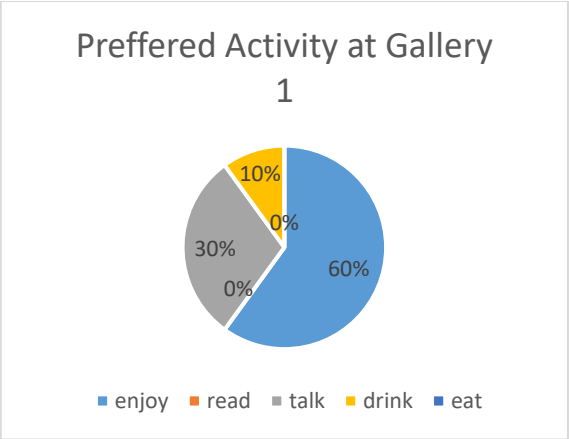

Figure 17. Preffered Activity at Gallery 1
Source: Author (2019)

Figure 18. Gallery 1 Special Collection
Source: Author (2019)

5. Conclusion

Figure 19. Gallery 1 Special Collection
Source: Author (2019)

Research conducted using the ASHRAE standard with physical and non-physical variables revealed that the thermal comfort in the Affandi museum was incompatible with the standards in the tropics. Physical variables in ASHRAE include temperature, RH and wind flow. While non-physical in the form of metabolism/activity and clothing/clo. Based on the measurement and questionnaire method, Gallery 1 with 87,5% respondents voted not comfortable. Although they voted for not comfort, they could enjoy gallery 1. Like the main gallery, Gallery 1 has many special collections such as Affandi's personal car,

some sculptures, Affandi's awards, and oil painting. In addition, gallery 1 has a special roof structure that resembles a banana leaf, a skylight, and fabric on it. Many visitors also wanted to improve gallery 1 thermal condition because gallery 1 feels too hot with low airflow and very humid.

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