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Observation of Thermal Comfort Standarts at The Gegerkalong KPAD Mosque, Bandung

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Abstract. Thermal comfort is a comfort that relates to the room's temperature conditions such as heat and cold which is manifested from the sensor on the skin and conveyed to the brain. So, the body can adjust the temperature to the surrounding environment. According to the American Standard of ASHRAE 55 of 2009, The purpose of this study is to analyze the suitability of the thermal comfort standard at the At-Taqwa Mosque of the GegerKalong KPAD. The research is conducted by measuring the thermal comfort at the At-Taqwa Mosque. It uses an anemometer measurement tool. The aspects of thermal comfort measured are wind speed, temperature, and relative humidity. The measurement results show that the thermal comfort at the At-Taqwa Mosque is still below the standard. The results of this measurement are simulated on three digital software which are named Sunhour, Flowdesign, and CBE Thermal Comfort. The results of the simulations on these three software show the thermal comfort at the At-Taqwa Mosque doesn't approve to standard of ASHRAE 55 of 2009 because the highest temperature is on the western exterior area with 33.5 C and the lowest is on the eastern interior area with 23.6 C.

Keywords: Thermal comfort measurement; At-Taqwa Mosque KPAD Gegerkalong; Sunhour; Flowdesign; CBE -Thermal

1. Introduction

Architecture is a production environment that is not only a link between humans and their environment, but acts as a container of expression that can regulate physical and psychological life (Robert Gautman). Therefore, architecture indirectly will shape human behavior according to its design. To design a building that is comfortable to use, an architect must pay attention to several factors, one of them is thermal comfort.

According to the American Standard ASHRAE 55 [2], thermal comfort is a condition where there is satisfaction with the harmonious ambient temperature conditions, suggesting that humans will express thermal comfort when the touchper cannot express whether he wants more changes in hot or cold temperatures in the room. [9]. Then, another definition is a state of mind which expresses satisfaction with the thermal environment when the variation occurs is large, both physiologically and psychologically between people [3]. The factors which affect thermal comfort in humans are divided into three [5], namely environmental, individual, and external factors. The role of the environment in thermal comfort can be measured in terms of humidity, temperature, and wind speed. Furthermore, individuals play a role in the body's metabolic system which releases heat with the influence of the activities carried out and the use of clothes used.



This study aims to determine thermal comfort by using simulations and analysis of thermal comfort factor data obtained in the field. Several previous studies have examined the openings that affect thermal comfort [7] and there are those who discuss thermal comfort using OTTV simulations [8]. However, the using of simulation in this study makes it easier to use because it is a plugin for a design application that is often used, namely Sketch up.

The choice of site for analysis is the At-Taqwa KPAD Mosque in Bandung because the potential of the mosque is widely used by the community so thermal comfort can be a very important factor in the comfort of the mosque. The measurements at the At-Taqwa Mosque KPAD Bandung provide some data, namely temperature, humidity, and wind speed. The results of the data obtained can be a determinant of thermal comfort at the At-Taqwa Mosque KPAD Bandung. The data obtained can be analyzed using ASHRAE and CBE Thermal Comfort standards. It can be a thermal comfort solution in the form of PMV and simulations with the sunhour plugin and flow design. So, the results of simulation and data analysis can be two of the bases for determining thermal comfort in a building.

2. Thermal Comfort

2.1. Literature Review

According to American Standard ASHRAE 55 [2], thermal comfort is a condition where there is satisfaction with the surrounding thermal conditions. The factors that influence thermal comfort in humans are divided into three [5], namely:

2.1.1. Environment. The environment in the tropics is a humid environment, one of them is the city of Bandung where has the following characteristics

2.1.1.1. Air Humidity. Humidity is the liquid in the air divided by the total air volume of the mixture or can be interpreted as the concentration of water vapor in the air. The intensity of air humidity in a place is very dependent on several factors as follows Santoso (2007): “temperature, air pressure, wind movement, quantity and quality of irradiation, vegetation, and water availability in a place (water, soil, water).” [11] Humidity can be measured with anemometer. Based on Meteoblue, the City of Bandung has experienced the significant seasonal variations in perceived humidity. On periode of 2019 has a muggier period (moist and hot) that lasts for 10 months from 25th September – 24th July. During the time, the comfort level is muggy, oppressive, or miserable (at least 67% of that time). The most humid and the hottest day (muggiest) of the year was April 23, with the least humid and hot conditions was almost 99% of the time. And, the most humid (but not too hot) was on August 23, with humid conditions was occurring at 57% of the time.

2.1.1.2. Temperature. Temperature is a measure of cold or heat. The unit of measurement for temperature is widely used in Indonesia is °C (degrees Celsius). While, the unit of measurement most widely used abroad is °F (degrees Fahrenheit). The average temperature in Bandung is 23.46 ° C with the maximum average temperature of 30.5 ° C (in September) and 28.2 ° C as the minimum average temperature.

2.1.1.3. Wind Speed. Wind speed can be influenced by several factors such as a location or a place, differences in air pressure, the height of place, and time. It can be measured with an anemometer or with flow design. Based on Meteoblue, the average wind speed per hour in Bandung goes through mild seasonal variations throughout the year. At the transition of 2018 - 2019, from 16th December to 6th March, the average wind speed was more than 2.23 m / s. January 31st was the peak, with an average of 2.72 m / s.

2.1.1.4. Average Solar Radiation. Radiation from the sun can influence the temperature so the temperature rises.

2.1.2. Individual. The human body emits heat. The heat which has taken out is influenced by the body's metabolic rate and clothing usage. The body's metabolic rate is influenced by the type of activity. The higher the intensity and quantity of activity, the more heat is released. Based on this, it is necessary to reduce the metabolic output which has taken out. So, overheating does not occur. Here are the tables of the metabolic rate of some activities [2].

Table 1. Metabolism of Activity

Activity	Metabolism (Constanta)	Activity	Metabolism (Constanta)
Seated, Quite	1.0	Lifting/packing	2.1
Reading, Seated	1.0	Heavy limb movement	2.2
Writing	1.0	Light machine work	2.2
Typing	1.1	Flying aircraft combat	2.4
Standing, relaxed	1.2	Walking 3mph	2.6
Filing	1.2	House cleaning	2.7
Flying aircraft, routine	1.2	Heavy vehicle	3.2
Filing, standing	1.4	Dancing	3.4
Driving a car	1.5	Calisthenics	3.5
Walking about	1.7	Walking 4 mph	3.8
Cooking	1.8	Tennis	3.8
Table sawing	1.8	Heavy machine work	4.0
Walking 2mph	2.0	Handing 100 lb	4.0

Reference: ASHRAE,2009

Clothing is also one of the dominant factors in influencing heat dissipation. The unit of insulation value of clothing that exists in thermal comfort is the clothing level. The following table shows the insulation level of clothing according to the type of clothing and its constants [2].

Table 2. Value of clothing insulation

Type of Clothing	Value of clothing insulation
Typical summer indoor clothing	0.5
Knee-length skirt, short-sleeve shirt, sandals, underwear	0.54
Trousers, short-sleeve shirt, socks, shoes, underwear	0.57
Trousers, long-sleeve shirt	0.61
Knee-length skirt, long-sleeve shirt, full slip	0.67
Sweat pants, long-sleeve shirt	0.74
Typical winter indoor clothing	1.0

Reference: ASHRAE,2009

2.1.3. External Factor. External factors are another factor that can affect thermal comfort. As in the object of this study, the influence of the surrounding buildings on the mosque is one of the external factors that can affect thermal comfort, especially in wind speed and solar radiation. Buildings can reflect, block, direct, and reduce or increase airflow velocity. The size of the influence of the building on air flow depends on height, width, length, and shape of the building [17].

2.2. PMV.

The PMV / PPD model is developed by P.O. Fanger uses heat-balance equations and empirical studies of skin temperature to determine comfort [6]. The Fanger equation is used to calculate the Predicted Mean Vote (PMV) of a group of subjects for giving combination of air temperature, average emission temperature, relative humidity, air velocity, metabolic rate, and clothing insulation. PMV with a zero value equals thermal neutrality and the comfort zone are determined based on a combination of the six PMV parameters that are within the recommended limits $[-0.5 < \text{PMV} < +0.5]$ [6]. [1] Although predicting the thermal sensation of a person or group is an important step in determining a comfortable state. It is also useful to consider whether a person is satisfied or not [4]. The CBE Thermal Comfort Tool for ASHRAE 55 allows the user to use six convenience parameters to define a specific combination according to ASHRAE 55

3. Method

Measurements implemented at the At-Taqwa Mosque in the Gegerkalong KPAD. This mosque is located in the northern part of Bandung City with the address on Jl. Gatot Raya Blok H No. 27, Gegerkalong, Sukasari District, Bandung City, West Java.

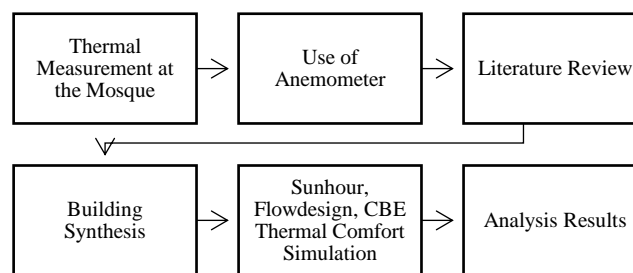


Figure 1. Chart of Analysis Methods

The method has used includes direct measurement by using the Anemometer on Saturday 28th September 2019, 07.00-17.00 WIB. Anemometer is used to get field data which includes temperature, wind speed, and humidity. In addition, the synthesis measurement used software consists of using SkecthUp with Sunhour Plugin which functions to see how long direct sunlight exposure to the building façade, and AutoDesk Flowdesign to simulate pressure from wind speed to the building façade. And, CBE Thermal Comfort is as a comparison of the suitability of the standards obtained from Anemometer measurements with the American Standard ASHRAE 55 in 2009 [2].

4. Results and Discussion

The following is an image of the At-Taqwa Mosque site plan at the Gegerkalong City in Bandung, the location of thermal comfort analysis which is located in the northern part of Bandung (Figure 2).

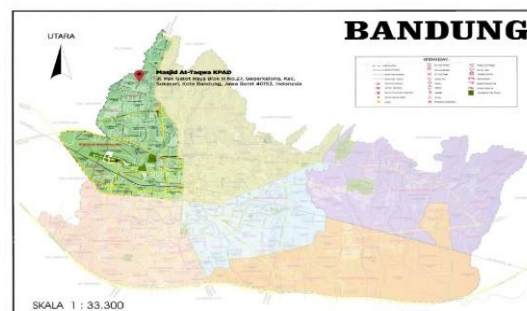


Figure 2. Map of the Bandung Region

The KPAD At-Taqwa Mosque building faces on the west. While on the east, it is the main entrance. Also, other doors on the north and the south (Figure 3).



Figure 3. At-Taqwa Mosque Block Plan

The environmental link around the site is very crowded. The building of the mosque is blocked by other buildings all around it.



Figure 4. Site Plan and Elevation of At-Taqwa Mosque Simulated on SketchUp Software

At-Taqwa Mosque is located at Jalan Gatot Raya Blok H No.27, Gegerkalong, Kec. Sukasari, Bandung City, West Java 40153. This mosque faces the west with the main door on the east side. A clear view can be seen in the following floor plan.

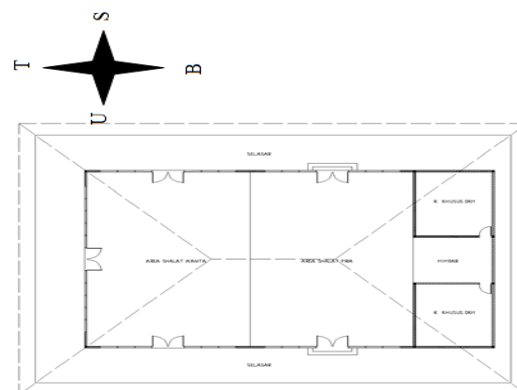


Figure 5. At-Taqwa Mosque Floor Plan

4.1 Measurement

4.1.1. *Measurement of Air Humidity, Temperature, and Wind Speed with Anemometer.* From the measurement of humidity, temperature and wind speed use an anemometer at the At-Taqwa Mosque KPAD Bandung. These are following results which are obtained

4.1.2. Interior. This mosque has four facades. The results of measurements of humidity, temperature and wind speed in the interior of the mosque show that; The air temperature varies every hour from each facade which ranges from 23-30 degrees Celsius. Indoor wind speed ranges from 0 - 1.6 m / s which has a slightly calm speed, which can be caused by wind obstructed by buildings [17] and also the type of Casement window openings.

Bottom-hung only brought in around 45% wind [18]. The humidity in the room ranges from 28-57%. The dynamics of changes in temperature, wind speed and humidity occur along with changes in time and hot sun in one day. This is also seen at 12.00 - 13.00, the humidity level is very low (below the level that is good for health according to medicine), which is below 45%. Significant results are in the east section, so further analysis will be carried out using CBE thermal comfort.

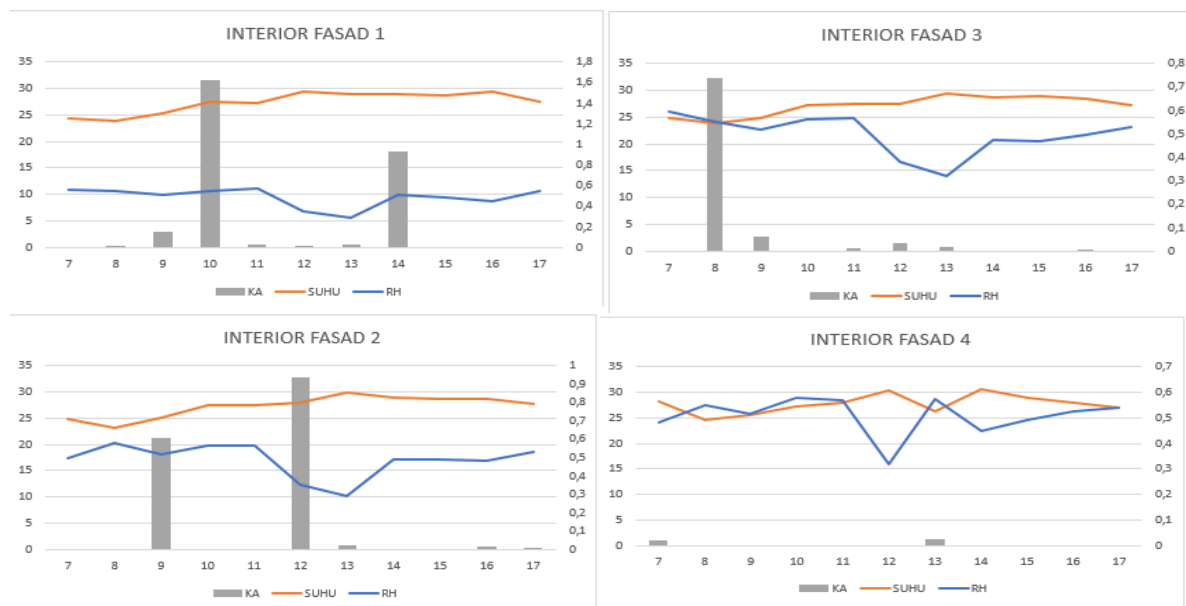


Figure 6. Measurement Results on the Mosque's Interior

4.1.3. Exterior. The results of measurements of humidity, temperature, and wind speed in front of the four facades of the mosque show that; The temperature varies hourly and per facade, ranging from 24-31 degrees Celsius. The wind speed in the room ranges from 0 - 0.75 m / s with a little calm according to the Beaufort scale. The quiet speed can be affected because there are buildings that surround the mosque building area. The humidity in the room ranges from 31-59%. The dynamics of changes in temperature, wind speed and humidity occur with changes in the hours of the day. The results of these measurements can also be evidence that temperature, humidity and wind speed are three related aspects because with increasing temperature the wind speed also increases. As temperature and wind speed increase, humidity will decrease.

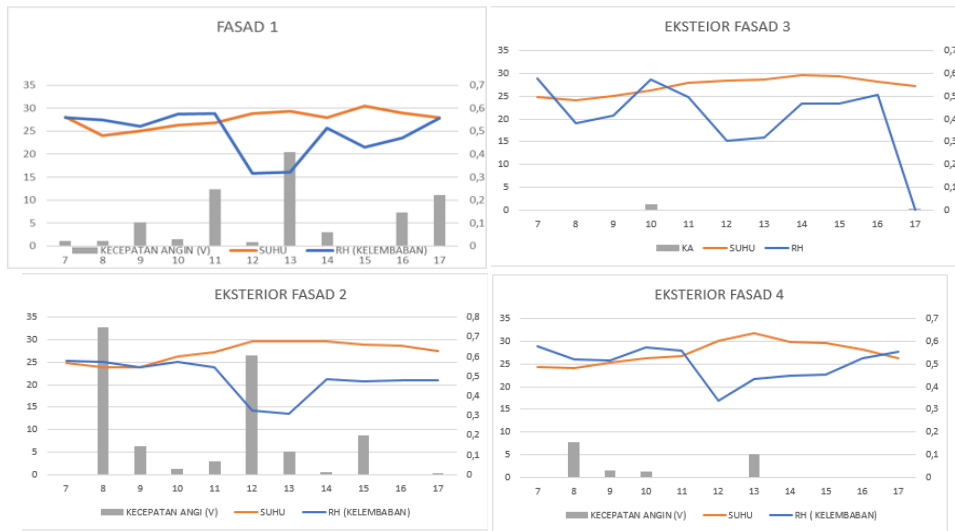


Figure 7. Measurement Results on the Mosque's Exterior

4.2. Simulation Results using SketchUp Software: Sunhours Plugin



Figure 8. Simulation Results using SketchUp: Sunhours Plugin

This plugin provides an assessment of the thermal comfort factor in the form of solar radiation. The measurement results using the SketchUp software: Sunhours Plugin show that the north and east facades are exposed to direct sunlight for 4-6 hours per day, because they are not shaded by other buildings so that they are exposed to direct sunlight on the buildings. . On the other hand, the south and west facades, which are dominated by blue, show the intensity of sun exposure below 2 hours per day because the surrounding buildings are more shady. So that the intensity of sun exposure can be caused by the presence of buildings and other entities. Both in the form of vegetation, buildings and canopies around the At-Taqwa Mosque KPAD Gegerkalong Bandung.

4.3. Simulation Results using AutoDesk software: FlowDesign

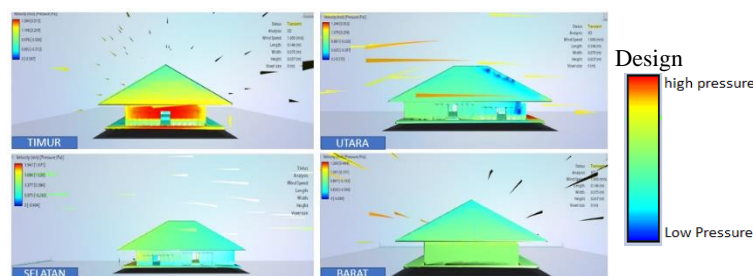


Figure 9. Simulation Results using AutoDesk software: FlowDesign

The simulation results with AutoDesk: FlowDesign software on each facade produce varying symptoms. This is due to the direction of the wind hitting the building, either directly or indirectly. The east facade is a facade that has a higher pressure than other facades when compared to the simulation results with existing parameters. This shows the highest pressure reaches 1.3 m / s. Meanwhile, the west facade is subjected to an average pressure of 0.8 to 1 m / s. Meanwhile, the south and north facades have an average pressure of 0.6 - 0.8 m / s. The cause of the east facade has a higher wind speed because there are no buildings blocking it [17] so that the wind goes directly to the east and flows the wind to the two openings in the north and south so that in the west the wind blows slowly. *Simulation results using CBE Thermal Comfort Tools.*

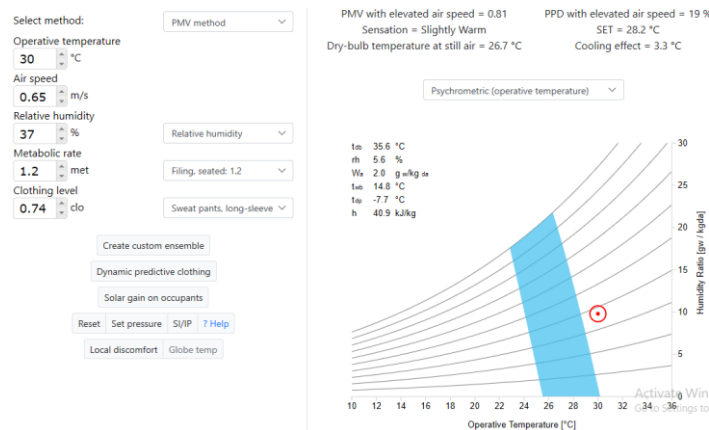


Figure 10. Simulation Results using CBE Thermal Comfort Tools: Exterior of Facade #2 (East Facade)

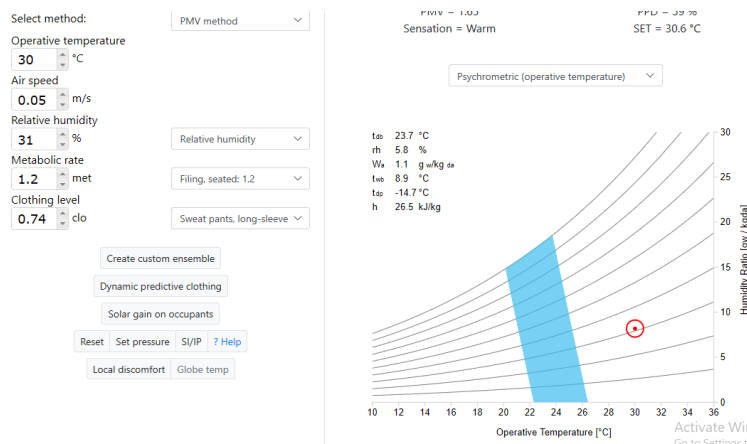


Figure 11. Simulation Results using CBE Thermal Comfort Tools: Interior of Facade #2 (East Facade)

Simulation using CBE Thermal Comfort Tools - Berkeley, University of California refers to the American standard ASHRAE 55 [2] which shows the blue area. It is a comfortable condition in an area meanwhile, the red circle is the result shown after inputting the obtained field data. Samples are taken on façade 2 (east), and the results showed that on facade 2 (east) the KPAD Gegerkalong mosque, Bandung. It is an area that does not meet the American thermal comfort standard [2] because it is above the standard, namely [. Value $[0.5 < PMV < +0.5]$. When viewed from the PMV value, the two simulation results are on the exterior, which is 0.81 with a slight warm sensation and the interior area has a PMV of 1.58 which is far above the standard with a warm sensation. If it is adjusted to the standard put forward by Fanger P. Ole (1970), the PMV obtained is more than the standard according to the sensation that is not neutral.

5. Conclusion

Based on the research results, it can be seen that the thermal comfort data of the At-Taqwa mosque in Gegerkalong KPAD Bandung has varied data at different times. However, it can be used as a means of determining thermal comfort. The highest temperature data is in the western exterior area (33.5 °C) and the lowest temperature is in the eastern interior (23.6 °C). The highest humidity of 61% in the interior west and the lowest humidity of 24% is found in the interior east. In addition, the highest wind speed of 0.75 m / s is found outside the west and the lowest wind speed of 0 m / s is found in almost every area at certain times. Another method used in this research is the Sunhour simulation which shows that the eastern and northern facades are exposed to sunlight because there are no buildings covering them. In contrast, the longest and shortest ones exposed to the sun are the western and southern facades.

Then, the Flow Design simulation shows that the east facade gets the highest wind pressure because there are no buildings blocking the way of the wind and vice versa the west facade gets the lowest wind pressure. In addition, by using the CBE - Thermal Comfort method with the east facade sample, it can be seen that the thermal comfort in the area has not been achieved according to the American standard ASHRAE 55 (2009) because the simulation results are found in the interior PMV. 0.81 and the exterior 1.58. Both are above the existing standard with a value of 0.5. So that the comfort of the at-taqwa mosque is categorized as uncomfortable. From the results of these data, thermal comfort can be measured by direct observation through measurement and also through simulation, namely by simulating sunhour to determine solar radiation by paying attention to external factors, flow design to determine wind speed by considering external factors, and CBE thermal Comfort to process factor data environment by paying attention to external factors and users.

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