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THE EFFECT OF THERMAL COMFORT ON THE HEALTH OF OCCUPANTS AT CITRA GRAHA HOUSING

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ABSTRACT

Humans mostly spend much time indoors, which is residential houses, so it is necessary to pay attention to thermal comfort because thermal comfort is closely related to health. Simple residential houses have the potential to cause thermal discomfort because simple houses are synonymous with dense settlements where building density is affected by the distance between buildings, building height, and building dimensions which will affect wind speed, temperature, and humidity. Thermal comfort is not only influenced by environmental aspects but also by one's condition. Although thermal comfort generally does not cause serious illness, it can significantly impact a person's quality of life and performance level. This study aims to analyze the thermal comfort in modest housing and the effect of thermal comfort on the health of the occupants. This research uses mixed methods, qualitative and quantitative, with data collection through direct field observation, simulation using Sefaira software and distribution questionnaires. The sample is a simple housing that is densely populated, namely Citra Graha Housing. Citra Graha Residential Housing residents feel thermal discomfort and depend on artificial ventilation in their homes. The results of this study indicate that the thermal comfort conditions of Citra Graha Housing do not meet ASHRAE 55 standards with relatively warm room conditions and tend to be hot throughout the day. Citra Graha housing already uses a type of opening that follows the Minister of Health Decree No.1077/MENKES/PER/V/2011 standard. Regarding the effect of thermal comfort on health, the variable thermal comfort partially does not affect health. Meanwhile, it simultaneously influences thermal comfort with a percentage of 54.7%.

KEYWORDS: Citra Graha Housing, Health, Sefaira Software, Thermal Comfort.

1. INTRODUCTION

Thermal comfort is one of the hot topics discussed because of the decreasing environmental quality, which includes the issue of climate change, significantly impacts human life. Climate change impacts various sectors, especially those related to thermal comfort and health, as well as economic sectors where the need for energy is increasing [1]. Thermal comfort is one of the sectors affected by climate change, which causes many people to pay more attention to the thermal comfort of a building. Thermal comfort ensures satisfaction with environmental temperature and related health [2].

Environmental aspects and personal aspects of the users influence thermal comfort. Environmental aspects include air temperature, wind velocity, humidity, and wind exchange rate (ventilation). Thermal comfort depends on individual aspects of its users, such as the type of activity carried out, clothing worn, age, health status, gender, and how the individual adapts to the local environment and climate. In addition, other factors can affect thermal comfort, such as population density in residential areas, culture in residential areas, building typology, and sun orientation, which also affect thermal comfort [3].

Thermal comfort is essential to note because there are many reasons related to the importance of thermal comfort to study. One of them is the relationship between thermal comfort and health. Thermal discomfort is not just a response to dissatisfaction with the ambient temperature but can potentially trigger health problems [4].

Indoor thermal comfort needs considering that most people spend much of their time in their homes. Especially since the Covid-19 pandemic hit the world, people must spend longer in their homes, such as working from home and carrying out learning and processes from home [5]. Although thermal comfort in residential homes generally does not cause serious illness, it can significantly impact a person's quality of life and performance.

In examining the effect of thermal comfort on the health of residents, this research took a sample of simple residential housing, namely Citra Graha Housing, Percut Sei Tuan District, and Deli Serdang Regency. Citra Graha Housing is a settlement whose buildings are arranged in a row which causes the houses in the housing to depend on the existing road. Those factors can affect the level of thermal comfort in the housing. The thermal discomfort felt by the occupants is the forerunner that affects the health of the occupants of Citra Graha Housing. Buildings arranged in Citra Graha Housing can cause thermal discomfort due to building density, which is affected by the distance between buildings, building height, and building dimensions. These conditions affect wind speed, temperature, and humidity [6].

Citra Graha housing has a population of 137 families. Based on interviews with the residents of Citra Graha Housing, the researchers obtained information that the residents of Citra Graha Housing felt thermal discomfort in their residential area which caused the residents to quickly feel dizzy when they were in the room for a long time if not assisted with artificial ventilation. In addition, throughout 2021, 20 residents of Citra Graha Housing were identified as exposed to the Covid-19 virus; this caused residents to find it challenging to carry out independent quarantine due to the thermal discomfort they felt in their residential environment.

The Citra Graha housing complex residents also stated that they sweat easily if not assisted with artificial ventilation. So that residents of Citra Graha Housing tend to use artificial ventilation such as air conditioners or fans because of the lack of inadequate ventilation in the housing. In addition, residents of these housing often use clothing made from cotton as a type of clothing used daily. Another phenomenon in these housing areas is that residents tend to sit and chat on the terraces of their homes because when they are on the terrace, they are easier to get wind.

In general, this study aims to analyze the thermal comfort conditions in modest housing. Specifically, this study aims to analyze the effect of thermal comfort on health, especially on Citra Graha's Occupants' health.

2. Object, Research Area and Research Method

2.1 Object and Research Area

Citra Graha Housing is a simple residential housing complex on Jalan Masjid Raya Al-Firdaus, Tembung, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra. The boundaries of the area are as follows.

1. To the north, it is bordered by residential areas on Jalan Masjid.
2. To the south, it is bordered by residential areas.
3. Residential areas border the west side.
4. To the east, it is bordered by Jalan Masjid Raya Al-Firdaus.

Access to Citra Graha Housing can be via Jalan Besar Tembung, then enter Jalan Masjid Raya Al-Firdaus or from Jalan Medan-Batang Kuis, then enter Jalan Masjid Raya Al-Firdaus.

This housing consists of 143 residential units with 61 housing units facing north, 47 housing units facing south, 18 housing units facing east, and 17 housing units facing west. This housing is divided into nine blocks with two groups of building areas, namely 45 m^2 and 72 m^2. However, after being occupied by the owner in the research area, it was found that the building area changed into three groups of building areas, namely 45-54 m^2, 72 m2 and >72 m^2. Where blocks B and C generally still maintain the existing shape of the house with an area of 45 m^2. Meanwhile, blocks I and J have done many renovations with a building area of >72 m^2 (Figure 1).

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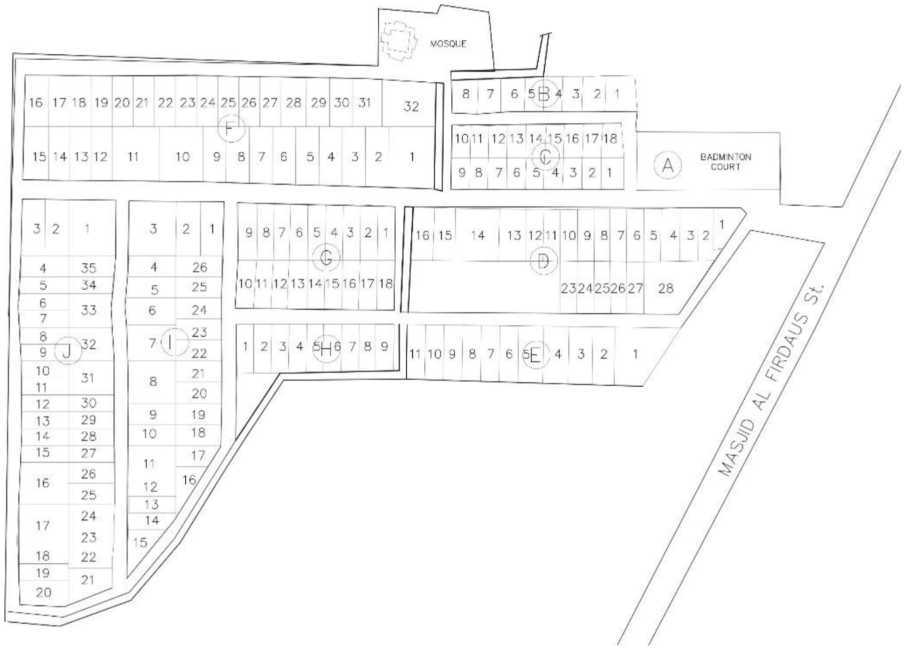

Figure 1: Citra Graha Housing Siteplan
Source: author, 2023

Four housing units will be sampled in this study to answer research problems related to the thermal comfort conditions of Citra Graha Housing. Where the sample is distinguished by the type and orientation of the house, the sample houses are sample 1 houses and sample 2 houses. The Sample 1 house is a type 45 house with a north and south orientation. Likewise, Sample 1 has Sample 2 house, a type 72 house with north and south orientation. The sample houses still maintain the existing condition with a maximum renovation percentage of 25%. As is the case with all the houses in Citra Graha Housing, the construction of the houses in samples 1 and 2, both north and south orientation, uses brick material with a painted finish. The house floor uses ceramic material, the ceiling uses gypsum material, the roof covering is made of zinc, and the house sills are made of wood.

Sample 1-north house is located in Block C-13, and sample 1-south house is located in Block C-4. The room configuration for sample 1 house consists of a terrace, living room, two bedrooms, kitchen and bathroom.

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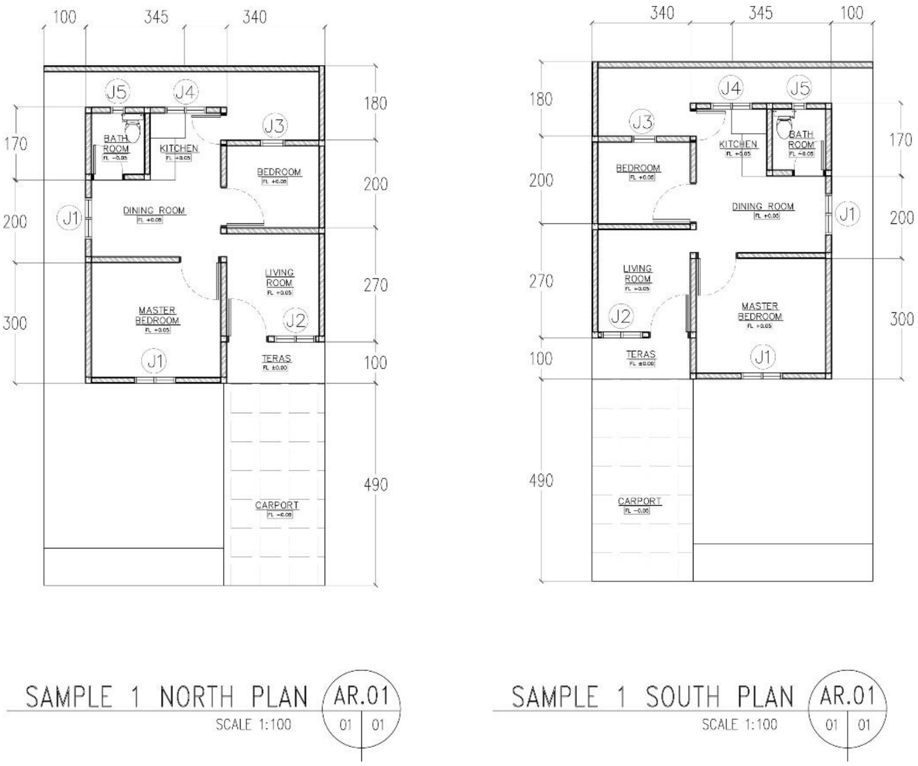

Figure 2: Sample 1 House (North & South) Plan
Source: author, 2023

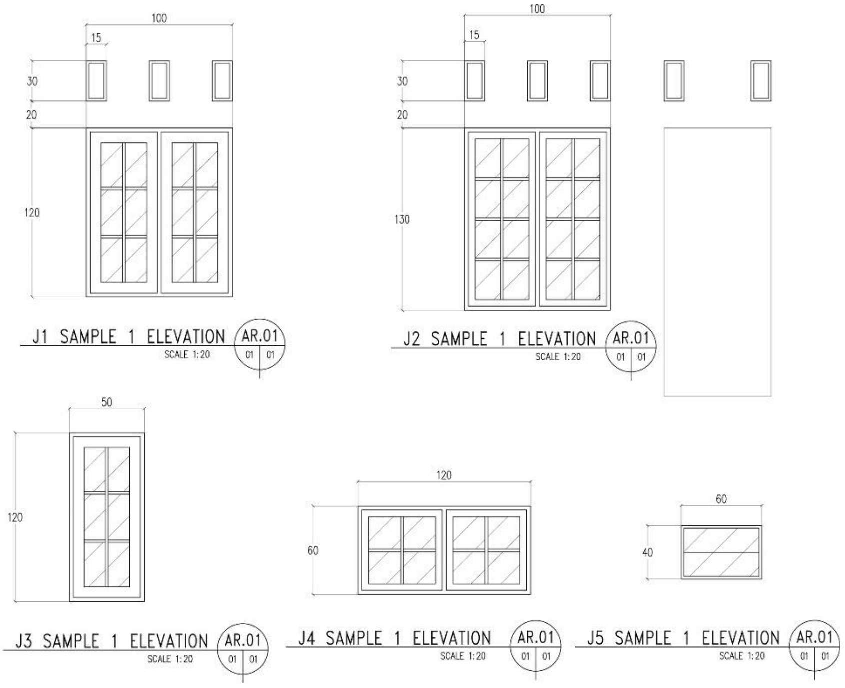

Figure 3: Openings Detail and Elevation of Sample 1 House (North & Elevation)
Source: author, 2023

Ventilation is one of the most important aspects of a residence as a medium for natural lighting and air quality because it can affect occupants' health [7]. In sample 1 houses, the openings consisted of two categories, namely openings that needed to be opened and closed in the form of doors, windows, and openings, namely ventilation. The position of the openings in sample 1-north and south houses are in the exact location. The openings in sample 1 house use the same wood material as all the houses in Citra Graha Housing. The windows used in sample 1 houses consist of 3 types, namely windows J1, J2, and J3, using top-hung casement windows. The J4 window uses a side-hung casement window type, while the J5 one uses a fixed one. Windows J1 to J4 is a window that needs to be opened and closed to maximize lighting and ventilation performance. Meanwhile, the J5 window is a type of fixed window that uses glass, and there is a gap between the two windows, so there is no need to open and close it. Windows J1 and J2 are equipped with always open ventilation, making it easier for the wind to enter the house.

This study used two samples of houses with different areas to compare the thermal comfort conditions between two categories of areas and two categories of different orientations. The sample 2 house with a north orientation is located in Block E, number 8, while the sample 2 house with a south orientation is located in Block D, number 23. The two houses still maintain the existing condition with the addition of a canopy and fence. The room configuration for sample 2 houses consists of a terrace, living room, family room, three bedrooms, two bathrooms, dining room and kitchen. Same with sample 1 house, the developer still provides 1 meter of space on one side of the house, which is the location of the opening in the house. This allows for openings located on the side of the house. For details of the location of the openings can be seen in the image below (Figure 4).

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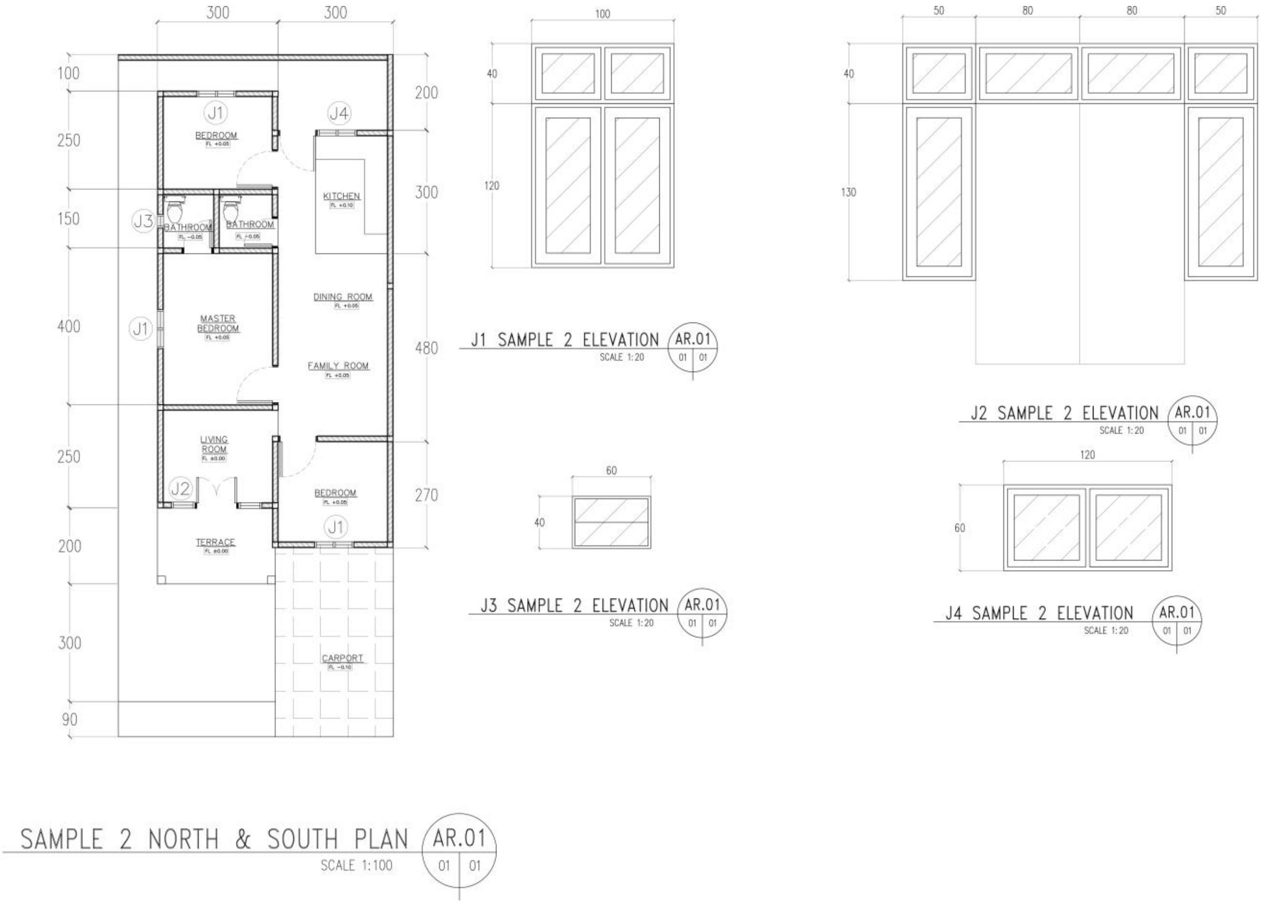

Figure 4: (a) Sample 2 North & South Plan, (b) Openings Detail and Elevation of Sample 2 House (North & South)
Source: author, 2023

Unlike the sample 1 house, sample 2 house only consists of openings in the form of windows and ventilation that need to be opened and closed, and there are no openings that are always open. The windows used in this house are casement top hung, side hung and fixed. All openings in the sample 2 house are the type that needs to be opened and closed. So that requires effort from house's occupants to obtain natural lighting and ventilation. Because the location of the ventilation is difficult to reach, the house's occupants seldom open the ventilation. Residents of sample 2 houses tend only to open windows in the morning when using artificial ventilation. Like in the sample 1 house, the door does not function as an opening because it tends to be closed all day long and only opens and closes when going out or entering a room.

2.2 Research Method

This study uses a mix-method research method, which combines qualitative and quantitative research methods [8]-[11]. The sampling method used was purposive sampling [12]. The data collection method was direct observation of the field and distribution of questionnaires. Observations were made to obtain data on the openings' size, temperature measurements, humidity and wind speed. Then the results of the observations of the sample houses were redrawn. Data from the measurement of openings will be analyzed by referring to the Regulation of the Minister of Health No. 1077/MENKES/PER/V/2011 [13]. Thermal comfort simulation was analysed using Sefaira software with the parameter analysis method ASHRAE 55 using PMV. The simulated data for thermal comfort conditions will be compared with the PMV and PPD index results from temperature, humidity and wind speed measurements.

Regarding the problem of the effect of thermal comfort on health, a questionnaire was distributed to obtain data related to occupants' perceptions and preferences regarding thermal variables. Data from the distribution of questionnaires were analyzed using the frequency method, which was processed in Microsoft Excel and will then be analyzed for its effect using multiple linear regression methods via SPSS.

3. DISCUSSION

3.1 Analysis of Field Observation Results

3.1.1 Measurement Results of Temperature, Humidity, and Wind Speed

Temperature, humidity and wind speed measurements were carried out using a thermometer, hygrometer and anemometer. Measurements were taken on May 20, 2023, at 09.00, 12.00 and 15.00. The measurement results data can be seen in the following table (Table 1).

Table 1: Measurements data for Sample 1 and 2 Houses on May 20,2023.

Sample		**Variable**		
		Air Temperature (°C)	Humidity (%)	Wind Velocity (m/s)
Sample 1 North	09.00	27,3	70	0
	12.00	30	61	0,2
	15.00	33,2	61	0,5
Sample 1 South	09.00	27	70	0
	12.00	29,6	60	0,5
	15.00	33	61	0,7
Sample 2 North	09.00	27,1	66	0
	12.00	31	61	0,5

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	15.00	34,5	60	1
Sample 2 South	09.00	27	66	0
	12.00	31	61	0,7
	15.00	34,7	60	0,7

The table above shows the measurements taken on May 20, 2023, in the living room/family room in samples 1 and 2 houses with the time range shown in the table above. The measurement results show differences in the measurements in samples 1 and 2 houses in the north and south orientation. Nonetheless, the differences were not too significant. Several things, including the house's orientation, the openings' dimensions and the types of openings and vegetation, can cause differences in measurement results. Based on the data shown in the table, there is an increase in air temperature in the afternoon. At the time of measurement, the weather was sunny and cloudy, and the wind was coming into the house.

3.1.2 Analysis of Openings in Sample Houses

Based on the data obtained during field observations, it was found that the use of casement windows, both top-hung and side-hung types, was very well implemented because they had a ventilation performance of 75% and 90%, respectively [14]. This allows the chance of wind entry into the room to be higher. However, a fixed window is used in the bathroom in these two samples. Even though using fixed glass, air can still enter and exit through the small gap between the two glasses.

Based on the Decree of the Minister of Health No.1077/MENKES/PER/V/2011 and the Ministry of PUPR (2019) [15], it is stated that a room should have an opening area of 5-10% of the floor area so that air circulation and lighting can be appropriately distributed. The data on the room area and opening area in samples 1 and 2 houses are as follows (Table 2).

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Table 2: Data on Space Area and Opening Area of Sample 1 and 2 Houses

Sample House 1					
No	**Room Name**	**Space Area**	**Window Width**	**Ventilation Area**	**Total Aperture Area**
1.	Family Room	6,6 m^2	1,3 m^2	0,225 m^2	**1,525 m^2**
2.	Master Bed Room	10,35 m^2	1,2 m^2	0,135 m^2	**1,335 m^2**
3.	Dinding Room	6,9 m^2	1,2 m^2	0,135 m^2	**1,335 m^2**
4.	Bedroom	4.9 m^2	0,6 m^2	-	**0,6 m^2**
5.	Bathroom	2,55 m^2	0,24 m^2	-	**0,24 m^2**
6.	Kitchen	3,3 m^2	0,72 m^2	-	**0,72 m^2**
Sample 2 House					
No	**Room Name**	**Space Area**	**Window Width**	**Ventilation Area**	**Total Aperture Area**
1.	Family Room	7,5 m^2	1,3 m^2	1,04 m^2	**2,34 m^2**
2.	Master Bed Room	8,1 m^2	1,2 m^2	0,4 m^2	**1,6 m^2**
3.	Bedroom 1	12 m^2	1,2 m^2	0,4 m^2	**1,6 m^2**
4.	Bedroom 2	7,5 m^2	1,2 m^2	0,4 m^2	**1,6 m^2**
5.	Bathroom	3 m^2	0,24 m^2	-	**0,24 m^2**
6.	Kitchen	9 m^2	0,72 m^2	-	**0,72 m^2**

Based on the calculations in the table above (Table 2), it can be concluded that in samples 1 and 2 houses, almost all met the standards set by the Minister of Health and the Ministry of PUPR. The bathroom in the sample 1 house was the only opening needed to meet the standard. Meanwhile, in the sample house, two openings that needed to meet the standards were located in the kitchen and

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bathroom. For this reason, it can be concluded that 75% of the rooms in samples 1 and 2 houses have met the opening area standards.

3.2 Analysis of Simulation Results

The simulation is carried out using the Sefaira computer engine, which is an analysis plug-in available in Sketch-Up and Revit. Simulations were carried out on 4 sample houses with different sizes and orientations to analyze the thermal comfort conditions of the houses. Parameters for thermal comfort analysis at Sefaira consist of dry bulb temperature, operative temperature, and ASHRAE 55 using PMV. However, in this study, the analysis of thermal comfort conditions that will be used is ASHARAE 55 using PMV so that the results can be compared with the results of field measurements analyzed with PMV index values.

3.2.1 Simulation Results of Sample House 1

Sample house 1-south is a sample house located in Block C-4 in Citra Graha Housing, oriented south with a 45m2 house type. Thermal comfort analysis was carried out using the ASHRAE 55 method using PMV. The results of the analysis of the thermal comfort condition of the sample 1-south house are as follows.

Figure 5: Results of Analysis of Thermal Comfort Conditions for Sample 1-South Houses Using Sefaira
Source: author, 2023

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The figure above (Figure 5) shows the results of the analysis of thermal comfort conditions in the southern sample-1 house based on the ASHRAE 55 analysis method using PMV values. In this study, PMV analysis was performed using a thermal sensation scale ranging from -1 to 1 using more than 98% of the hour. The thermic sensation scale range between -1 to 1 was chosen because this range can still be categorized as comfortable. After all, -1 is a slightly cold condition, 0 is a neutral or comfortable condition, and 1 is a slightly warm condition. At the same time, 98% of use hours is the standard Sefaira recommends. If the room simulation results show -1 – 1, the room can be declared thermally comfortable. The simulation results show that only the east side area meets the ASHRAE 55 Standard and is declared comfortable according to the results of the PMV analysis. In contrast, the areas on the south, north and west sides were declared as not meeting the standards and uncomfortable, whereas the north area was the most uncomfortable zone with a percentage of not meeting the standards of 65.4%.

Based on the simulation results, it can be seen that the percentage of thermal comfort in sample 1-south houses averages 35% in three zones, namely the north, south and west zones. All three zones were declared too hot for 64% of the hours. Only zone 4 or those on the east side are declared thermally comfortable with a comfort percentage of 100%. Thus, it can be concluded that the 1-south sample house does not meet the thermal comfort criteria with a failure percentage of >50%.

Next is to analyze the 1-north sample house. The thermal comfort analysis process in the 1-north sample house is the same as the 1-south sample house simulation process. The results of the analysis are as follows.

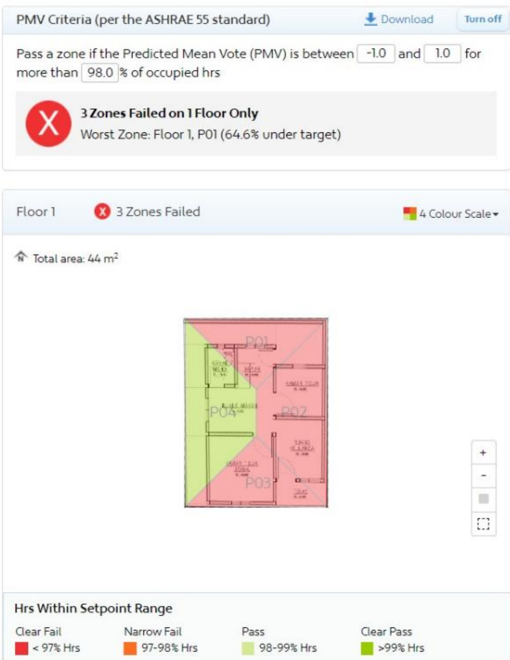

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Figure 6: Results of Analysis of Thermal Comfort Conditions for Sample 1-North Houses Using Sefaira
Source: author, 2023

The results of the thermal comfort for Sample 1-North House (Figure 6) that analysis using the ASHRAE 55 standard with a thermal index value range of -1 – 1 indicate that almost all rooms in sample 1-north houses do not meet the thermal comfort conditions referring to the thermal sensation scale. The figure shows that the room in the 1-north sample house tends to overheat 65% of the hour daily. This causes the percentage of thermal comfort in the house to average only 35% hours per day. Even though zones are declared comfortable, more space in the house is declared thermally uncomfortable.

3.2.2 Simulation Results of Sample House 2

In this study, an analysis was carried out on 2 sample houses with differences in area size and building orientation. In sample 2-south, the procedure and simulation process were carried out the same way as in sample 1. The analysis results of thermal comfort conditions are as follows (Figure 7).

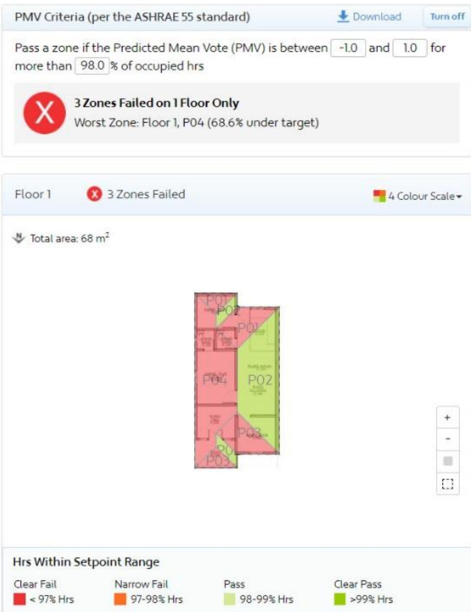

Figure 7: Results of Analysis of Thermal Comfort Conditions for Sample 2-South Houses Using Sefaira
Source: author, 2023

The simulation results show that several points of space are considered comfortable based on the ASHRAE 55 standard: the family room, the bedroom on the back, and the terrace. However, based on

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the simulation results, only the family room was comfortable. For the rest, all the rooms in the 2-south sample house were declared unsatisfactory and uncomfortable based on ASHRAE 55, with a failure rate of 68.6%.

The picture above shows that the west side is the most comfortable based on the simulation results using Sefaira, with a comfortable percentage of 100% hours/day. In addition, the simulation results are dominated by the red zone, which means the room is too hot and uncomfortable, with an average percentage of the room’s tendency to overheat by 55% hours per day. This causes the percentage of comfort in all spaces in the house to be 63%. This is what causes the results of calculations related to energy consumption for cooling in this house to have an enormous value.

After analyzing the 2-south sample house, the 2-north sample house will be analyzed. This is done to compare the results of thermal comfort conditions at different areas and orientations. The simulation process in the 2-north sample house is no different from that in the previous sample house. The results of the thermal comfort analysis in the 2-north sample house are as follows (Figure 8).

Figure 8: Results of Analysis of Thermal Comfort Conditions for Sample 2-North Houses Using Sefaira

Source: author, 2023

Based on the thermal comfort simulation results in the 2-north sample house, it looks the same as those in the 2-south sample house. Even though they look the same, the percentage of failure to meet thermal comfort in the sample 2-north house is smaller than in the sample-south house, where the failure

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percentage value in the 2-north sample house is 62.1% which is 6.5% smaller than the 2-south sample house.

In contrast to the 2-south sample house, the east side is the most comfortable area with a percentage of 100% hours/day based on the simulation results. Even though it has similar results to the 2-south sample house, the average percentage tendency of the room to overheat in the 2-north sample house is smaller than the 2-south sample house, which is 42.7% hours/day. The simulation results show that the room in the 2-north sample house feels too hot for almost half a day; this causes the use of artificial ventilation to be extensive, which causes energy consumption for ventilation in this house of 1416 kWh

3.3. Analysis of Questionnaire Results

Questionnaires were distributed from 13-26 May 2023. Of the 30 respondents, 57% were women, and 43% were men (Figure 10), with the predominance of respondents aged 40-50 (Figure 9). Most respondents live in blocks C and E, the study's sample houses (Figure 11). The average respondent has lived in the residence between 5-10 years (Figure 12). Furthermore, the number of occupants in an average residential house is 4-5 people, with a percentage of 57% (Figure 13).

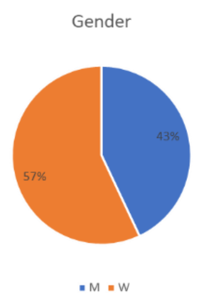

Figure 2: Gender of Respondents

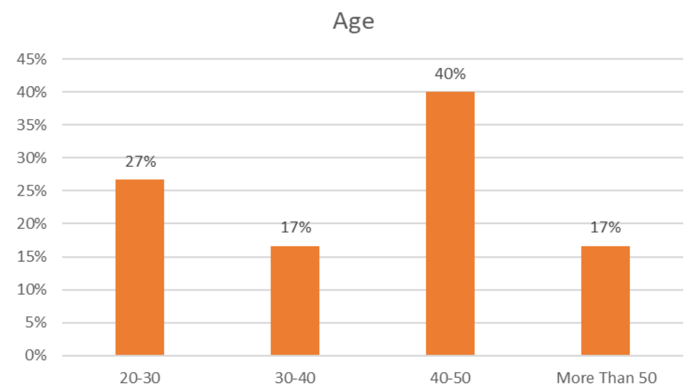

Figure 1: Respondents' Age

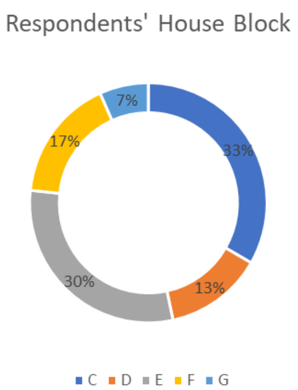

Figure 3: Respondents' House Block

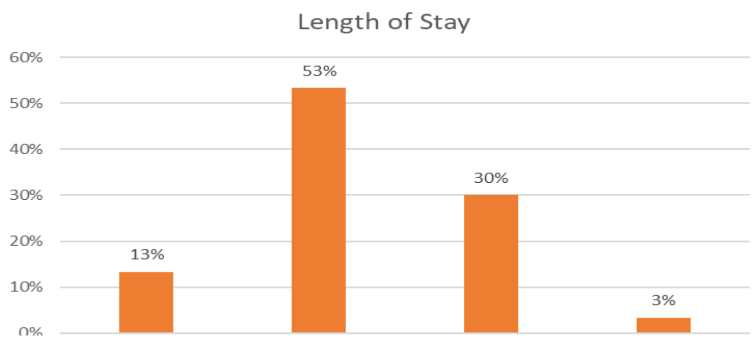

Figure 4: Respondents' Length of Stay at Their House

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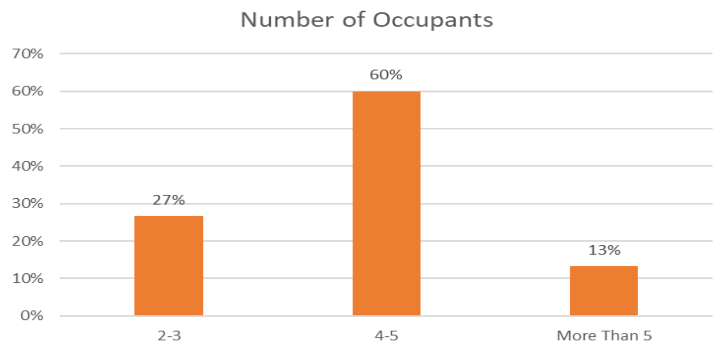

Figure 5: Number of Occupants in Respondents' House
Source: author, 2023

Furthermore, the statements in the questionnaire consist of factors that affect thermal comfort, namely temperature, wind speed, humidity, activity (met) and type of clothing (clo). These factors are independent variables that will affect the dependent factor, namely the health of the occupants. The answers to the statements in the questionnaire use a Likert scale of 1-5 where each category has its scale, namely, 1 (Strongly Disagree); 2 (Disagree); 3 (Slightly Agree); 4 (Agreed); and 5 (Strongly Agree). Statements related to occupants' perceptions of the thermal comfort of their environment consist of 8 statements, where statements number 3 & 4 relate to temperature variables, statements numbers 5 & 6 relate to wind speed variables, numbers 7 & 8 relate to humidity, number 9 relates to activity (met) and number 10 related to the type of clothing (clo). The assessment results of occupant perceptions of thermal comfort are as follows (Table 3).

Table 3: Results of Respondents' Questionnaire Answers

No	Question	SD	D	SA	A	SA
1	P3 (Air Temperature)	0	13	6	11	0
2	P4 (Air Temperature)	0	0	2	8	20
3	P5 (Wind Velocity)	0	4	10	16	0
4	P6 (Wind Velocity)	0	3	3	11	13
5	P7 (Humidity)	1	13	7	7	2

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No	Question	SD	D	SA	A	SA
6	P8 (Humidity)	0	6	5	11	8
7	P9 (Metabolic Rate)	2	22	0	5	1
8	P10 (Clothing Level)	0	0	4	6	20

3.4 Analysis of Thermal Comfort Conditions

After analyzing each data collection method, the next step is to analyze the thermal comfort conditions at Citra Graha Housing by combining the data obtained from the results of field observation analysis with the results of questionnaire analysis to answer research problems related to thermal comfort conditions at Citra Graha Housing. The analytical method used is PMV which refers to the ASHRAE-55 standard. Measurements were made using the CBE Thermal Comfort Tool. The calculation includes the operative temperature, wind speed, humidity, metabolic rate, and clo.

3.4.1 The Results of the Thermal Comfort Condition of the Sample House 1

To obtain PMV index values and PPD values, some data is needed, namely effective temperature, wind speed, humidity, metabolic rate, and the type of clothing used. These data were obtained from the results of field observations and distributing questionnaires discussed in the previous sub-chapter. In the PMV and PPD index simulation using CBE Thermal Comfort, the metabolic rate data or activity carried out by occupants is resting, sitting/relaxing, which has a value of 1 metre. This value of 1 metre is used for 09.00 and 15.00. Meanwhile, at 12.00, the type of activity carried out is cooking with a met value of 1.8. In this simulation, the types of clothing used are everyday clothes, namely short-sleeved shirts, knee-length shorts/skirts, underwear and sandals, which have a value of 0.54 clo.

Table 4: Results of PMV and PPD Index Values of Thermal Comfort on Sample 1 Houses

Variable	Sample 1-North			Sample 1-South		
	09.00	12.00	15.00	09.00	12.00	15.00
Air Temperature (°C)	27,3	30	33,2	27	29,6	33
Humidity (%)	70	61	61	70	60	61
Air Velocity (m/s)	0	0,2	0,5	0	0,5	0,7
Operative Temperature (°C)	28,7	30,1	31,7	28,4	29,7	31,4

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Variable	Sample 1-North			Sample 1-South		
	09.00	12.00	15.00	09.00	12.00	15.00
Metabolic Rate (met)	1	1,8	1	1	1,8	1
Clothing Level (clo)	0,54	0,54	0,54	0,54	0,54	0,54
PMV	**1,33**	**1,18**	**1,41**	**1,21**	**0,81**	**1,11**
PPD	**42%**	**34%**	**46%**	**36%**	**19%**	**31%**

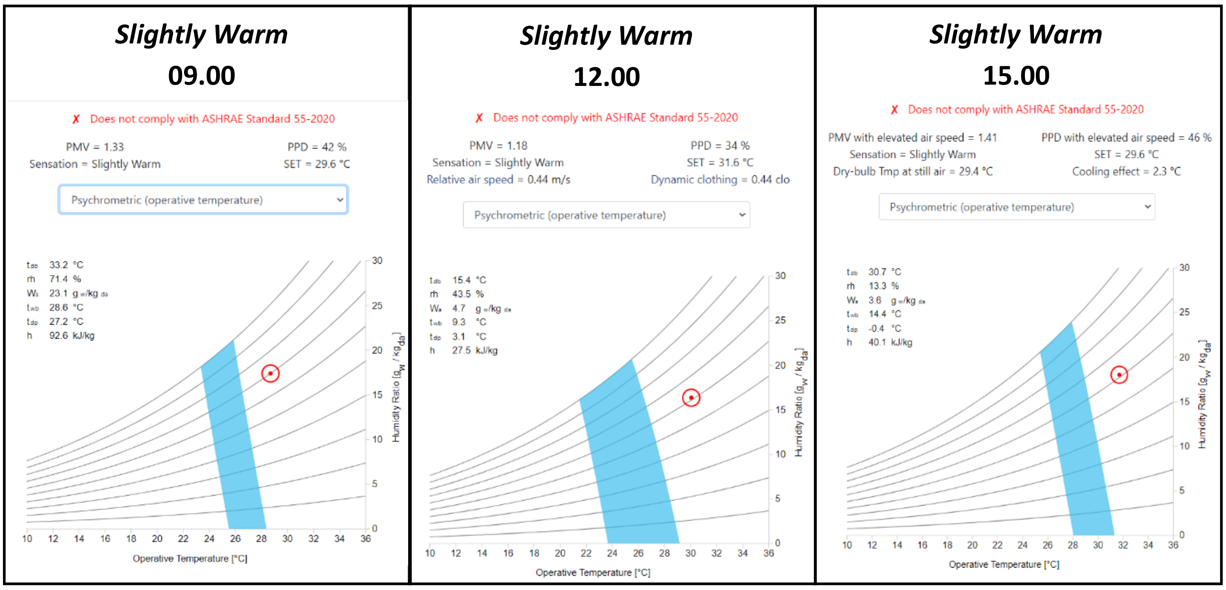

Figure 6: Results of PMV and PPD Values of Sample 1-North Using CBD Thermal Tool
Source: author, 2023

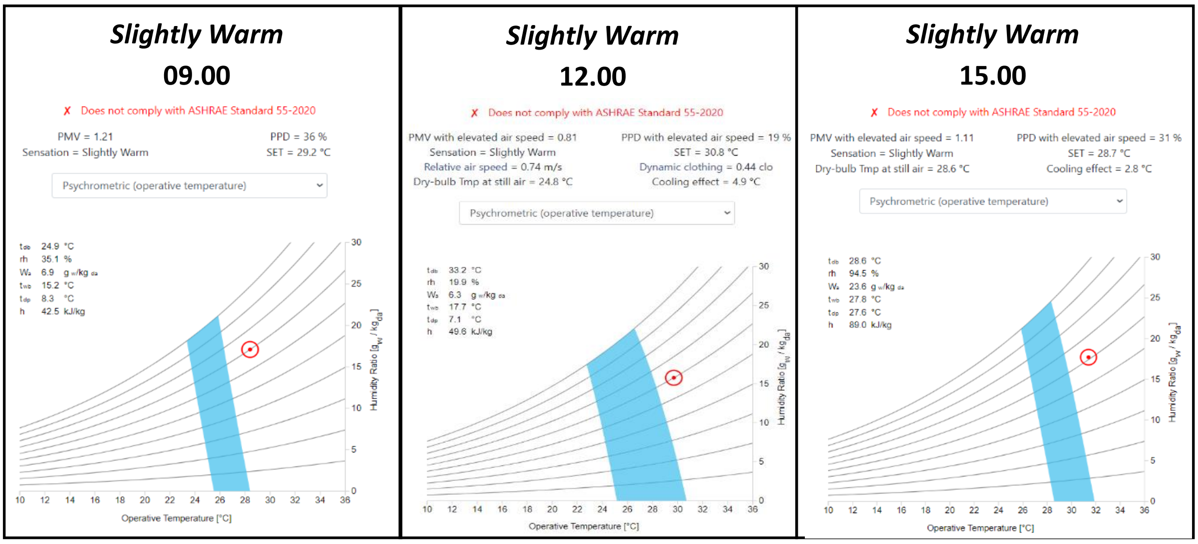

Figure 7: Results of PMV and PPD Values of Sample 1-South Using CBD Thermal Tool
Source: author, 2023

Based on the table (Table 4) and graph above (Figure 14-15), it can be seen that none of the conditions in sample 1 house followed the ASHRAE 55 standard, and all results for PMV values were positive. The results of this calculation are almost the same as the simulation results using Sefaira. Both PMV values using the CBE Thermal Tool and simulations using Sefaira show positive PMV values or room conditions tend to be hot.

In this study, apart from using quantitative methods, experimental methods were also used with computer engine simulations. Based on the simulation results of thermal comfort in sample houses 1-north and south of Citra Graha Housing, it shows that these houses do not pass the criteria for thermal comfort. So that either by direct measurement or computer simulation, the thermal comfort conditions in sample 1 houses (north and south) were concluded to be thermally uncomfortable and did not meet the ASHRAE 55 standard, with the house conditions being somewhat hot and tending to heat. Moreover, the results of distributing the questionnaires show that residents want a change in temperature in their residential area to obtain thermal comfort in their environment.

3.4.2 The Results of The Thermal Comfort Condition of the Sample 2 House

This research used two housing units with different areas as samples. This aims to identify whether the difference in the area contributes to thermal comfort in the building. The data collection method and data variables used to obtain PMV and PPD values in sample 2 houses were the same as in sample 1 houses. The PMV and PPD values for sample 2 houses are as follows (Table 5).

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Table 5: Results of PMV and PPD Index Values of Thermal Comfort on Sample 2 Houses

Variable	Sample 1-North			Sample 1-South		
	09.00	**12.00**	**15.00**	**09.00**	**12.00**	**15.00**
Air Temperature (°C)	27,1	31	34,5	27	31	34,7
Humidity (%)	66	61	60	66	61	60
Air Velocity (m/s)	0	0,5	1	0	0,7	0,7
Operative Temperature (°C)	29	31	32,7	29	31	32,8
Metabolic Rate (met)	1	1,8	1	1	1,8	1
Clothing Level (clo)	0,54	0,54	0,54	0,54	0,54	0,54
PMV	**1,40**	**1,12**	**1,42**	**1,40**	**1,00**	**1,63**
PPD	**46%**	**31%**	**47%**	**46%**	**26%**	**58%**

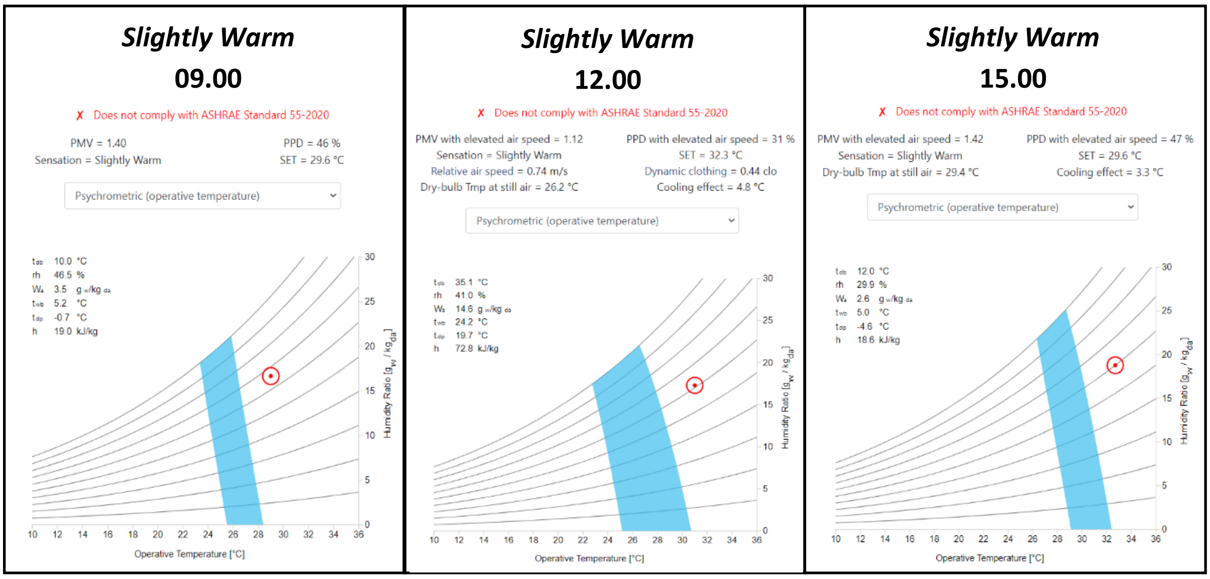

Figure 16: Results of PMV and PPD Values of Sample 2-North Using CBD Thermal Tool

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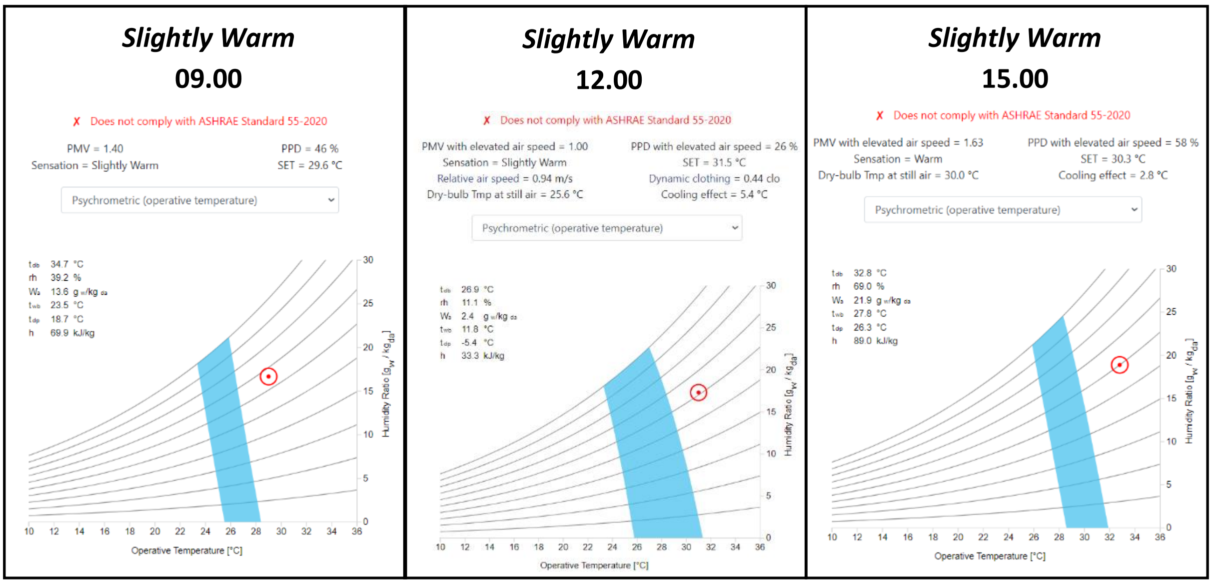

Figure 17: Results of PMV and PPD Values of Sample 2-South Using CBD Thermal Tool

The table and graph above show the PMV and PPD index values results for sample 2 houses, both north and south orientation. Based on the graph above (Figure 16-17), it can be seen that the results of PMV and PPD values in sample 2 houses are higher than in sample 1 houses. This can happen because of the elongated shape of sample 2 houses, with the number and area of openings almost the same as sample 1 houses. So with the temperature conditions, humidity, wind speed, type of activity and clothing used is more accessible to fulfil thermal comfort in sample 1 than in sample 2. This shows the influence of building area on thermal comfort in buildings.

Based on the simulation results using the Sefaira software, it is stated that the sample 2 house does not meet the thermal comfort standard. Based on the results of direct measurements and simulations using software, sample 2 houses (north and south orientation) are less comfortable thermally, with the house feeling relatively warm and tending to heat. Also, the effect of the size of the building area and openings on the results of thermal comfort in the house.

3.5 Analysis of the Effect of Thermal Comfort on the Health of Citra Graha's Occupants

After processing the questionnaire results using the frequency method in Microsoft Excel, the next step is to analyze the effect of thermal comfort on health using multiple linear regression in SPSS. Testing is done by testing the value of the t-test and F-test with a confidence level of 95%, a = 0.05.

2.2.1 Results of Test t

The test was carried out to obtain the results of the t-test, which aims to determine whether the independent variable on the dependent variable gives a partial effect. The results of the t-test are as follows (Table 6).

Table 6: Results of t-Test by SPSS

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3.886	10.864		-.358	.724
	Air Temperature (X1)	-.285	1.160	-.045	-.245	.809
	Air Temperature (X1.2)	.194	1.640	.021	.118	.907
	Air Velocity (X2)	1.630	1.480	.205	1.101	.283
	Air Velocity (X2.2)	-4.849	1.169	-.821	-4.146	.000
	Humidity (X3)	-.078	1.015	-.014	-.077	.939
	Humidity (X3.2)	3.916	1.284	.741	3.050	.006
	Metabolic Rate (X4)	-.605	1.189	-.102	-.509	.616
	Clothing Level (X5)	2.230	1.239	.283	1.800	.086
a. Dependent Variable: Health (Y)						

In this study, the t-table value was 2.080. For this reason, the t-test result value must be greater than the t-table value to declare the variable valid. Based on the table above, according to the respondents, almost all of the independent variables do not affect the occupants of Citra Graha Housing. Only the humidity variable influences the health of the occupants.

3.5.2 Results of Test F

The F-test was carried out to determine whether the independent variable on the dependent variable gives a simultaneous effect. The results of the F test are shown in the following table (Table 7).

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Table 7: Results of F-Test by SPSS

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	524.213	8	65.527	3.167	.016[b]
	Residual	434.493	21	20.690		
	Total	958.706	29			
a. Dependent Variable: Health (Y)						
b. Predictors: (Constant), Clothing Level (X5), Air Temperature (X1), Air Temperature (X1.2), Humidity (X3), Air Velocity (X2.2), Air Velocity (X2), Metabolic Rate (X4), Humidity (X3.2)						

The F table value in this study is 2.40, so that the variable can be declared valid, the F test result value must be greater than the F table. Based on the output shown in the table above, it can be seen that the significance value for the influence of variables X1, X1.2, X2, X2.2, X3, X3.3, X4 and X5 on Y is 0.16 > 0.05 and the value of F count 3.167 > F table 2.40. So, the thermal comfort factors together significantly influence the health of the occupants. This proves the theory by Fanger and ASHRAE that thermal comfort is affected by temperature, humidity, wind speed, activity and type of clothing [16]-[17]. These factors together have a significant impact on influencing one's assessment of the thermal conditions of the environment. The results of the F-test scores conducted on Citra Graha Housing residents show that residents agree that thermal comfort factors can affect their health simultaneously.

3.5.3 Determination Coefficient Results

The coefficient of determination was analyzed to determine how much the independent variables simultaneously contributed to the dependent variable. The value of the termination coefficient ranges from 0-1. If the results are close to 1, the independent variable provides almost all the information or influence needed to predict the dependent variable. However, if the value is close to 0, it indicates that the ability of the independent variable to explain the dependent variable is minimal [18]. The results of the coefficient values are terminated in the study of the Effect of Thermal Comfort on the Health of Residents of Citra Graha Housing as follows.

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Table 8: Determination Coefficient Results by SPSS

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.739[a]	.547	.374	4.549
a. Predictors: (Constant), Clothing Level (X5), Air Temperature (X1), Air Temperature (X1.2), Humidity (X3), Air Velocity (X2.2), Air Velocity (X2), Metabolic Rate (X4), Humidity (X3.2)				

The table above (Table 8) shows the results of the analysis of the coefficient of termination, where the value of R Square is 0.547. This shows that the influence of thermal comfort factors simultaneously on health has a percentage of 54.7%. Moreover, the thermal comfort factors simultaneously significantly influence health (the dependent variable). At the same time, the remaining 45.3% is influenced by other variables not tested in this study. These results are to the theory put forward by Ormandy and Ezratty that thermal comfort not only ensures the level of satisfaction with environmental temperature, but thermal comfort cannot be separated from health [19].

CONCLUSION

Based on the results of the study, it can be concluded that the thermal comfort conditions of sample 1 and 2 houses, both north and south orientation, were declared to be less comfortable thermally and did not meet the ASHRAE 55 standard by calculating the PMV and PPD index values and the simulation results using the Sefaira software with room conditions feeling slightly hot and tends to be hot throughout the day. The orientation and building area influence thermal comfort with the same thermal conditions and variables; south-oriented sample houses have a higher percentage of comfort than north-oriented houses. Also, the sample 1 house is more comfortable than the sample 2. The types of openings used in Citra Graha Housing are casement top hung, casement side hung and fixed, and 75% of the openings in the housing have met the standards set by the Decree of the Minister of Health No.1077/ MENKES/PER/V/2011. Regarding the effect of thermal comfort on health, the variable thermal comfort partially does not affect health. However, simultaneously the variable thermal comfort influences health with a percentage of 54.7%.

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