The Influence of Building Facade Design on Thermal Comfort in Classroom Case Study: Nasima Elementary School Semarang

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Keywords: Thermal, Comfort, Façade, Building orientation

Abstract: Thermal comfort is an essential element in the learning process. Nasima Elementary School Semarang was built in a densely populated area. To meet space requirements, development prioritizes land efficiency. It results in a difference in thermal comfort in the classroom. Data of air, humidity, temperature, and radiation is collected and analyzed to determine the effect of building orientation and facade design on thermal comfort in the classroom compared to Mom-Weisebron comfort parameters. The study found that many classrooms on the 2nd and 3rd floors do not fit into the Mom-Weisebron standard. The average effective room temperature on the 2nd Floor is higher than on the 3rd Floor. It is due to differences in elevation, differences in the design of the building facades and environmental conditions. The movement of air in the room needs to be increased. A fan can be applied so that the effective temperature of the room is included in the criteria for optimal comfort according to Mom-Wiesebron standards. If the application of a fan has not been able to lower the effective temperature so that it is categorized as optimal comfort according to Mom-Weiseborn standards, then AC needs to be used.

1 INTRODUCTION

In the design process, there are four comfort factors in buildings that must be considered: room comfort, visual comfort, audibility comfort, and thermal comfort. Visual comfort in buildings is needed so that humans can do their activities properly. Local climatic conditions influence the level of productivity and human health. If the climatic conditions are in accordance with human physical needs, productivity can reach its maximum point (Victor, 1963).

One of the factors that influence Thermal comfort is the building façade (Mangunwijaya, 1997). The building facade is a part of the building that is often exposed to solar radiation. The direction of building orientation has a significant influence on the effectiveness of the function of the building facade. One of the building facade tasks is to regulate the conditions around the outside of the classroom, which aims to ensure comfortable conditions in the room.

The thermal comfort limit for low conditions ranges from a lower limit of 19°C TE to 26°C TE. At 26° C TE, many humans start to sweat. The most suitable comfort limit for Indonesians used in this study is the Mom-Wiesebron comfort limit as follows: (Soegijanto, 1998).

Table 1. Mom-Wiesebron Comfort Zone Criteria

Criteria	Effective Temperature (TE)
Cool Comfortable	20,5°C TE - 22,8°C TE
Optimal Comfortable	22,8°C TE s.d. 25,8°C TE
Warm Comfortable	25,8°C TE s.d. 27,1°C TE

2 RESEARCH METHODS

The object of writing is the classroom in Nasima Elementary School Semarang. Classrooms are facilitated with air conditioning for comfort in the teaching and learning process. In their everyday use, the windows tend to be closed by curtains, for thermal comfort, by preventing the entry of solar radiation heat into the room, so the classroom uses Air Conditioner for temperature control all day long.

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Figure 1. Existing Condition of Nasima Elementary School

The collection of field measurement data for selected classrooms on the 2nd and 3rd Floor was carried out on Saturday, May 20, 2017, where the classrooms were empty and the weather conditions were sunny. Measurements are carried out every 1 hour from 07.00-16.00 WIB. This time is chosen with the consideration that at that time, the classroom is used for teaching and learning activities.

The measurement of thermal comfort is carried out at 18 measuring points, namely eight measuring points in the selected classroom on the 2nd Floor and one measuring point outside the 2nd-floor classroom and eight measuring points in the selected classroom on the 3rd Floor and one measuring point outside the classroom on the 3rd Floor.

The analysis begins with processing field measurement data, namely: Dry Air Temperature (DBT), Air Humidity (RH), and Air Movement. Furthermore, using the Psychometric Diagram to determine the Wet Temperature (WBT) with the determining indices, namely Dry Air Temperature (DBT) and Air Humidity (RH).

Analysis of the effective temperature in the Classroom of Nasima Elementary School Semarang is carried out in two ways, the first model analysis by processing the measurement results in the field in the form of dry temperature, humidity, and air movement in the room and the second model of practical temperature analysis is carried out by processing the measurement results in the field in the form of dry temperature. Humidity with air movement are assuming to be at the lowest point at a speed of 0.1m/sec. The adequate temperature data obtained are then used to determine thermal comfort in school buildings using the thermal comfort index according to the Mom-Wiesebron criteria (Soegijanto, 1998).

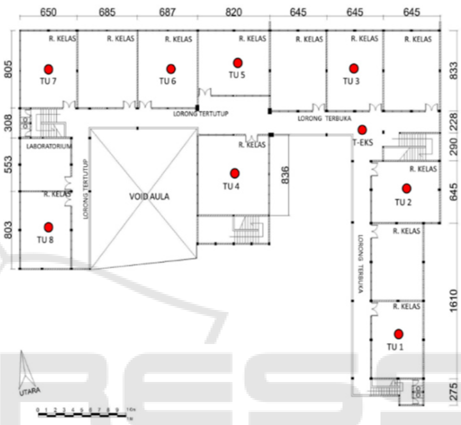


Figure 2. Location of Thermal Measurement Points 2nd Floor and 3rd Floor Classroom Building

Table 2. Measuring instruments used in the current research

Instruments	Branded
Hot Wire Anemometer	Krisbow 0.1-25 m/s
4 in 1 Environment Meter	Lutron Lm-8000
Laser Distance Meter	Bosch DLE-40

3 RESULTS AND DISCUSSION

The classroom in Nasima Elementary School Semarang are facilitated with two air conditioning and one ceiling fan. In table 3 is the following explanation of the existing data in the Nasima Elementary School Classroom.

Table 3. Classroom Nasima Elementary School Semarang

Parameter	Data
Square Measurement Room Area	45-68 m2
Ceiling Height	3.6 m
Room Capacity	25 people

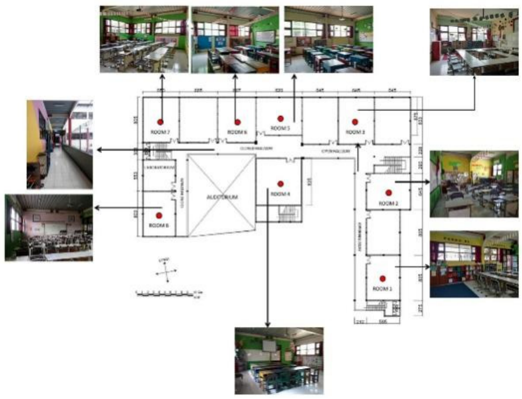
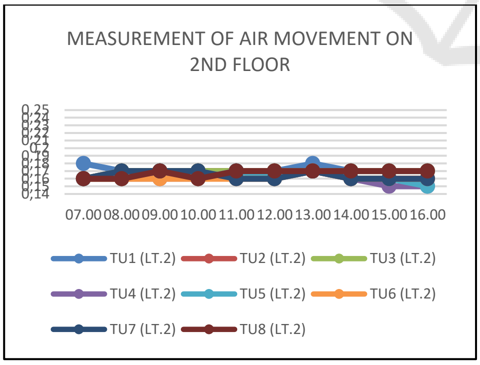


Figure 3. Floor Plan of Nasima Elementary School with the existing Classroom

3.1 Air Movement

Air movement data is obtained at the measuring point of the 2nd and 3rd Floors with the conditions of the empty classroom and open windows. The measuring point for air movement is taken in the middle of selected classrooms on the 2nd and 3rd floors from 07.00 to 16.00 WIB.



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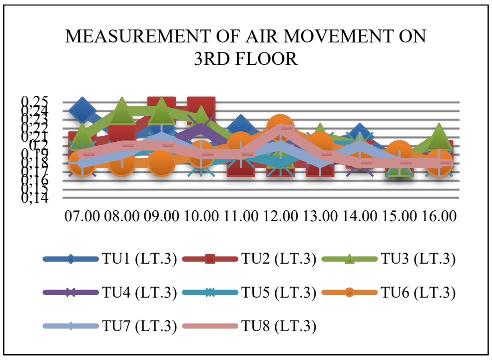


(b)

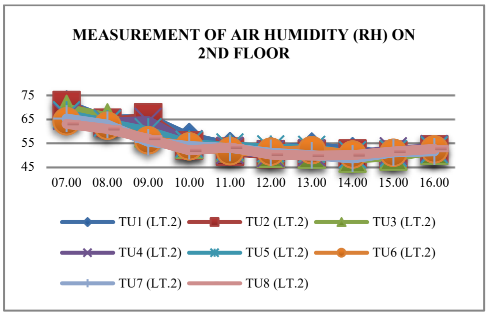
Figure 4. Field Measurement Graphic in Nasima Elementary School Classroom. (a) Measurement of Air Movement on 2nd Floor (b) Measurement Of Air Movement on 3rd Floor

To maintain a comfortable conditions, the airspeed should be in the range of 0.15 m / s to 0.25 m / s. [8] It can conclude from Table 4 that the air movement of both the 2nd and 3rd floors has reached the criteria for air movement in the room, with the air movement on the 2nd Floor lower between 0.01-0.07 m/sec compared to the 3rd Floor.

The wind speed outside the classroom on the 3rd Floor is faster than on the 2nd Floor. The movement of the wind on the 3rd Floor gets less factor from the surrounding objects, such as buildings and trees. This condition results in air movement in the classroom on the 3rd Floor. It is higher than the 2nd Floor even though the classroom has window openings of the same size and shape because the airflow velocity is influenced by the height of the building and the materials around the building (David, 1975). The greater the ratio of the outlet area to the inlet, the higher the wind speed in the room so that the room is cooler (Becket & Godfrey, 1974). To increase the volume of wind entering the room, the opening should occur cross-ventilation (Francis, 1997).

3.2 Air Humidity

Air humidity measurements are carried out by opening all window openings in selected classrooms from 07.00 to 16.00 WIB with sunny weather conditions throughout the day. In the measurement at 07.00 WIB, the exterior air humidity on the Second Floor is 69.3% with a dry temperature of 29.5°C, and on the third Floor, it is 69.2% with a dry temperature of 29.6°C. Dry temperature is inversely proportional to air humidity. The air in the morning is higher than the humidity in the afternoon because the moisture content in the morning is higher than in the afternoon. This condition occurs because of the low heat of solar radiation and dry temperatures in the morning (Georg, 1994).



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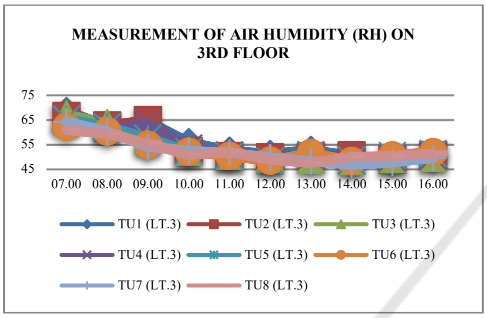

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Figure 5. Field Measurement Graphic in Nasima Elementary School Classroom.
(a) Measurement of Air Humidity on 2nd Floor
(b) Measurement of Air Humidity on 3rd Floor

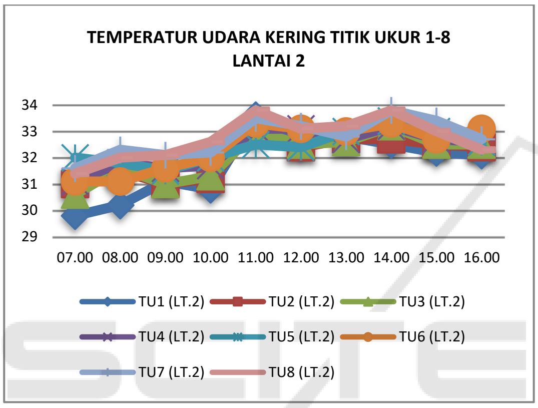
Table 5. Measurement of Air Humidity on 2nd Floor and 3rd Floor

MEASUREMENT OF AIR HUMIDITY (RH) ON 2ND FLOOR												
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	Avg
ROOM 1	TU 1	71,1	64,6	65,3	57,5	53,7	52	53,5	51,6	50,3	52	57,16
ROOM 2	TU 2	70,9	63,5	65,8	54	51,4	50,3	50,5	50,6	50,1	52,3	55,94
ROOM 3	TU 3	69,3	65,7	59	54,3	52,8	50,5	50,2	48,5	49,4	51,8	55,15
ROOM 4	TU 4	66,2	63,5	64,1	54,8	52	50,6	51	50,2	51,8	52,7	55,69
ROOM 5	TU 5	66,9	63,2	59,8	54,5	53,4	52,6	52,4	50,1	50,7	52,2	55,58
ROOM 6	TU 6	64,1	62,2	56,1	53,6	51,6	51,4	52	50,2	50,9	52,3	54,44
ROOM 7	TU 7	65,2	62,6	55,4	53,7	52,9	50,9	49,9	48,5	51	51,5	54,16
ROOM 8	TU 8	62,9	60,8	56,7	51,9	53,1	50,1	49,7	49,9	51,4	52,5	53,9
AVERAGE		67,1	63,3	60,3	54,3	52,6	51,1	51,2	50	50,7	52,2	
MEASUREMENT OF AIR HUMIDITY (RH) ON 3RD FLOOR												
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	AVERAGE
ROOM 1	TU 1	68,5	62,6	64,4	55,8	52,4	51	52,7	50,2	49,3	50,2	55,71
ROOM 2	TU 2	66,5	62,6	64,8	52,3	50,2	49,6	50,1	50,4	48,8	50,5	54,58
ROOM 3	TU 3	67,1	63,5	56,7	52,1	50,5	49,3	48,7	48,1	49,2	49,5	53,47
ROOM 4	TU 4	65,4	61,4	63,5	53,5	50,7	48,4	50,1	48,3	49,5	50,1	54,09
ROOM 5	TU 5	65,3	62,2	57,5	52,2	50,2	48,2	50,9	48,7	50,5	51,3	53,7
ROOM 6	TU 6	62,1	60,2	54,8	52	50,2	48,3	51,4	48,2	50,5	51,8	52,95
ROOM 7	TU 7	64,2	60,2	53,9	52,3	51,5	49,6	48,1	46,7	47,6	49,4	52,35
ROOM 8	TU 8	60,8	59,2	55,3	50,6	51,8	48,7	47,4	49,8	50,2	51,1	52,49
AVERAGE		65	61,5	58,9	52,6	50,9	49,1	49,9	48,8	49,5	50,5	

The recommended relative humidity for tropical areas for dense user spaces ranges from 55% - 60% (Badan Standarisasi Nasional, 2001). From table 5, it can be seen that the humidity on the 2nd Floor is between 48.5 to 71.1%, and the humidity on the 3rd Floor is between 46.7 to 68.5%. The 2nd and 3rd floors humidity tends to be above the maximum limit of indoor air humidity from 07.00 and 08.00 WIB and is below the minimum limit from 10.00 to 16.00 WIB and only on the range at 09.00 WIB. This condition occurs due to the absence of vegetation in the area around the building so that solar heat radiation can enter the building directly. With the influence of vegetation when the air moves under the tree canopy, the temperature begins to decrease because the sun's heat radiation is filtered by the leaves (Terry, 1987).

3.3 Dry Temperature

In determining thermal comfort, one of the influencing factors is dry temperature. In measuring dry temperature in selected classrooms, there is a difference in dry temperature on the 2nd Floor and 3rd Floor. It is caused by several factors, namely the angle of incidence of sunlight, altitude, wind direction, ocean currents, clouds, and duration of sun exposure (Georg, 1994).



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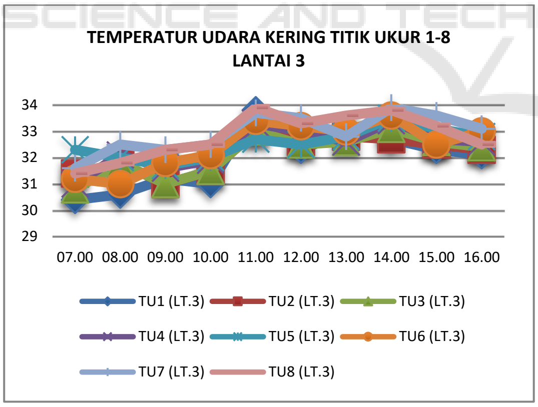

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Figure 6. Field Measurement Graphic in Nasima Elementary School Classroom.
(a) The dry temperature on 2nd Floor
(b) (b) Dry Temperature on 3rd Floor

The TU7 classroom has the highest average effective temperature on the 2nd and 3rd floors. This room is on the west side of the school building, with canopy window openings in north and west orientations facing the outside of the school building.

In May, the sun is on the north side of the equator so that the heat of daylight solar radiation can enter the room through the tile canopy window in the north orientation. In addition, in the afternoon, the sunset to the west side caused solar radiation to enter the classroom via a canopy window in a western orientation (Georg, 1994). Heat enters the building through a conduction process (through walls, roofs, glass windows), and solar radiation transmitted through windows/glass causes dry temperatures in the room to be high (Basaria, 2005).

Table 6. Measurement of Dry Temperature on 2nd Floor and 3rd Floor

MEASUREMENT OF DRY TEMPERATURE ON 2ND FLOOR												
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	Avg
ROOM1	TU 1	29,8	30,2	31,1	30,8	33,6	32,5	32,8	32,5	32,2	32,1	31,76
ROOM2	TU 2	31	31,5	31	31,2	33,1	32,4	32,7	32,7	32,5	32,4	32,05
ROOM3	TU 3	30,6	31,6	31	31,3	33	32,5	32,6	33,2	32,5	32,5	32,08
ROOM4	TU 4	31,1	31,8	31,6	31,7	33,1	33,1	32,7	33,2	32,7	32,6	32,36
ROOM5	TU 5	32	31,8	31,5	32	32,5	32,4	33	33,4	33	32,6	32,42
ROOM6	TU 6	31,1	31,1	31,6	32	33,3	33,1	33	33,3	32,7	33,1	32,43
ROOM7	TU 7	31,6	32,3	32,1	32,2	33,5	33,2	32,8	33,8	33,4	32,7	32,76
ROOM8	TU 8	31,4	32	32,1	32,6	33,8	33,1	33,2	33,8	33	32,3	32,73
AVERAGE		31,1	31,5	31,5	31,7	33,2	32,8	32,9	33,2	32,8	32,5	
MEASUREMENT OF DRY TEMPERATURE ION 3RD FLOOR												
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	AVERAGE

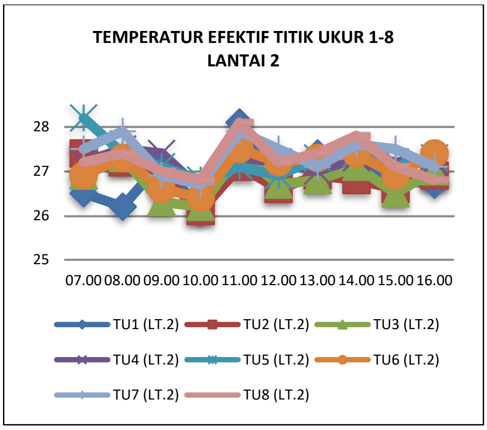
Table 6. Measurement of Dry Temperature on 2nd Floor and 3rd Floor (cont.).

ROOM 1	TU 1	30,4	30,6	31,2	31	33,8	32,3	33	32,7	32,3	32,1	31,94
ROOM 2	TU 2	31,4	31,8	31	31,5	33	32,6	32,8	32,7	32,5	32,3	32,16
ROOM 3	TU 3	30,8	31,8	31	31,5	33	32,5	32,6	33,1	32,6	32,4	32,13
ROOM 4	TU 4	31	32,1	31,6	31,9	33,3	33	32,6	33,4	32,7	32,6	32,42
ROOM 5	TU 5	32,3	32	31,7	32	32,7	32,5	32,8	33,5	33,1	32,8	32,54
ROOM 6	TU 6	31,2	31	31,8	32,1	33,4	33,2	33	33,6	32,5	33	32,48
ROOM 7	TU 7	31,6	32,5	32,3	32,5	33,7	33,5	32,8	33,9	33,6	33,1	32,95
ROOM 8	TU 8	31,4	31,8	32,3	32,5	33,9	33,3	33,6	33,8	33,2	32,5	32,83
AVERAGE		31,3	31,7	31,6	31,9	33,4	32,9	32,9	33,3	32,8	32,6	

The dry temperature of both the 2nd Floor and 3rd Floor is low in the morning then high in the afternoon, as described in table 6. The difference in dry temperature on the 3rd Floor is higher between 0.1-0.6°C than on the 2nd Floor. The 3rd-floor measuring point is higher than the 2nd Floor; even though the classroom has a similar facade design and openings, it is due to the elevation of the classroom on the 3rd Floor, which is higher than the 2nd-floor classroom so that the classroom is exposed to solar radiation longer.

3.4 Effective Temperature Analysis

Processing data carried out an analysis of the effective temperature of the first model in selected classrooms from the measurement results in the field, namely in the form of dry temperature, humidity and air movement data on measurements on May 20, 2017. And the analysis of the effective temperature of the second model was carried out by processing the measurement data in the field in the form of temperature dry and humidity. At the same time, the air movement is assume to be at a speed of 0.1m /s.



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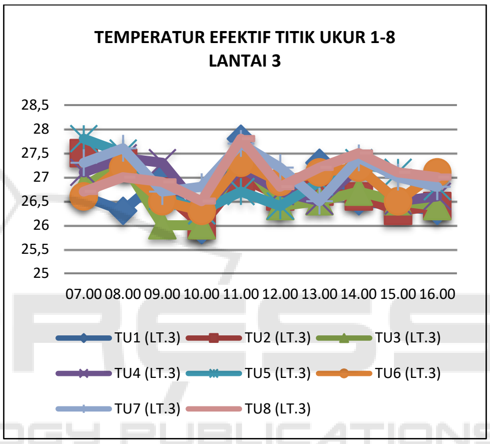

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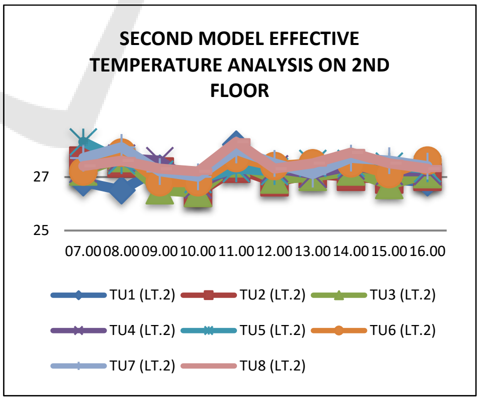

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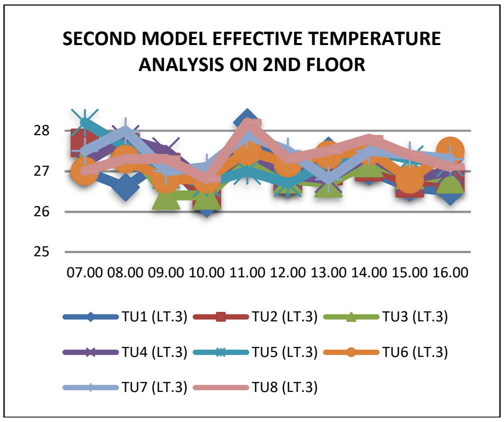

(d)

Figure 7. Field Measurement Graphic in Nasima Elementary School Classroom.
(a) First Model Effective Temperature on 2nd Floor
(b) First Model Effective Temperature on 3rd Floor
(c) Second Model Effective Temperature on 2nd Floor
(d) Second Model Effective Temperature on 3rd Floor

The research results show that the effective temperature on the 3rd Floor tends to be lower than the 2nd Floor, especially at the measuring points TU1, TU2, and TU3. This condition is influenced by the orientation of the building with the openings protected from direct sunlight so that the classroom is protected from the heat of solar radiation (James, 1994).

3.5 Thermal Comfort Analysis of the First Model Mom-Wiesebron

According to the Mom-Wiesebron thermal comfort standard, the effective temperature is in the criteria of cool comfort between 20.5-22.8 ºC TE, optimal comfort between 22.8-25.8 ºC TE, and warm comfortably between 25.8-27.1 ºC TE. In comparison, temperatures below 20.5 ºC TE are categorized as cold and above 27.1 ºC TE are categorized as hot (Soegijanto, 1998). The first model of thermal comfort analysis is carried out using field data in the form of the same dry temperature and humidity and air movement results of field measurements. The thermal comfort analysis using the Mom-Wieseborn standard in the first model obtained the results of the comfort level as in Table 7.

Table 7. First Model Thermal Comfort Level

THERMAL COMFORT LEVEL ON 1ST MODEL ON 2ND FLOOR											
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
ROOM 1	TU 1	26,5	26,2	27,2	26,1	28,1	26,9	27,4	27,1	26,8	26,7
ROOM 2	TU 2	27,4	27,2	26,9	26,1	27,1	26,6	26,9	26,8	26,6	26,9
ROOM 3	TU 3	26,9	27,3	26,3	26,2	27,4	26,7	26,8	27,1	26,5	27
ROOM 4	TU 4	27,2	27,5	27,4	26,6	27,3	27,2	27	27,3	27,2	27,2
ROOM 5	TU 5	28,2	27,4	27,1	26,8	27,1	26,9	27,3	27,4	27,1	27,3
ROOM 6	TU 6	26,9	27,7	26,6	26,4	27,5	27,2	27,3	27,4	26,9	27,4
ROOM 7	TU 7	27,5	27,9	26,9	26,7	27,9	27,5	27,1	27,6	27,5	27,1
ROOM 8	TU 8	27,2	27,4	27	26,9	28,1	27,2	27,4	27,8	27,1	26,8
AVERAGE		27,2	27,3	26,9	26,5	27,6	27	27,2	27,3	27	27,1
THERMAL COMFORT LEVEL ON 1ST MODEL ON 3RD FLOOR											
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
ROOM 1	TU 1	26,6	26,3	27	25,9	27,8	26,4	27,3	26,5	26,4	26,3
ROOM 2	TU 2	27,5	27,3	26,7	26	27	26,6	26,7	26,6	26,3	26,4
ROOM 3	TU 3	26,8	27,4	26	26	27,3	26,4	26,5	26,7	26,5	26,4
ROOM 4	TU 4	27,1	27,4	27,3	26,3	27,2	26,7	26,5	27,2	26,5	26,6

Table 7. First Model Thermal Comfort Level (cont.).

(continued Table 7) THERMAL COMFORT LEVEL ON 1ST MODEL ON 3RD FLOOR											
ROOM 5	TU 5	27,8	27,5	26,6	26,3	26,7	26,4	26,9	27,3	27,1	26,8
ROOM 6	TU 6	26,6	27,6	26,5	26,3	27,3	26,9	27,1	27,2	26,5	27,1
ROOM 7	TU 7	27,3	27,6	26,7	26,8	27,7	27,2	26,5	27,4	27	26,8
ROOM 8	TU 8	26,7	27	26,9	26,5	27,8	26,8	27,2	27,5	27,1	27
AVERAGE	27,1	27,3	26,7	26,3	27,4	26,7	26,8	27,1	26,7	26,7	AVERAGE

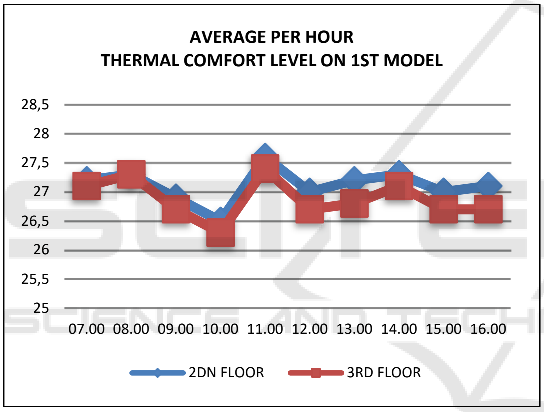

Figure 8. Graph of Average Per Hour of First Model Thermal Comfort

Air movement is influenced by the shape and orientation of the openings of each classroom, the elevation of the classroom and the wind speed outside the room. The classroom location on the 3rd Floor is higher than the 2nd Floor allows the wind to enter the classroom to get fewer obstacle factors, such as buildings and surrounding trees, (David, 1975) resulting in higher air movement in the 3rd-floor classroom, between 0.01-0.07. m /s, compared to the air movement of the 2nd-floor measuring point even though the 3rd-floor classroom has the same size and design of the opening as the 2nd-floor classroom. This condition results in the effective temperature at the 3rd-floor measuring point, which tends to be lower than the effective temperature of the 2nd Floor.

The results of the analysis of the average effective temperature per hour on the 3rd Floor, which is in the warm comfort category, are valued at between 26.3 s.d. 27.1 ° C TE, which is 07.00 to 10.00 WIB and 12.00 to 16.00 WIB. Meanwhile, 11.00 WIB is in the hot category with a temperature of 27.4 ° C TE. The lowest average effective temperature per hour on the 2nd Floor is 0.2 ° C TE higher than the 3rd Floor, and the highest average effective temperature per hour on the 2nd Floor is 0.02 ° C TE higher than the 3rd Floor.

3.6 Thermal Comfort Analysis of the Second Model Mom-Wiesebron

Model Second of Thermal comfort analysis according to the Mom-Weiseborn standard has obtained the level of comfort according to Table 8. The lowest effective temperature of the 2nd Floor at the TU2 measuring point at 10:00 WIB of 26.2°C TE is included in the warm, comfortable category. The highest effective temperature for the second Floor is at the TU5 measuring point at 07.00 WIB at 28.4°C, which is categorized as hot.

Table 8: Second Model Thermal Comfort Level

THERMAL COMFORT LEVEL ON 2ND MODEL ON 2ND FLOOR											
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
ROOM 1	TU 1	26,8	26,5	27,3	26,4	28,2	27,1	27,5	27,3	26,9	26,8
ROOM 2	TU 2	27,6	27,5	27,2	26,4	27,3	26,8	27,1	27	26,9	27
ROOM 3	TU 3	27,2	27,7	26,5	26,4	27,5	26,9	27	27,2	26,7	27,1
ROOM 4	TU 4	27,3	27,7	27,6	26,7	27,4	27,3	27,1	27,4	27,2	27,2
ROOM 5	TU 5	28,3	27,6	27,1	26,9	27,3	27,2	27,5	27,5	27,4	27,3

Table 8: Second Model Thermal Comfort Level (cont.).

ROOM 6	TU 6	27,2	27,9	26,8	26,8	27,7	27,4	27,5	27,5	27,1	27,6
ROOM 7	TU 7	27,7	28,1	27,2	27	28	27,5	27,1	27,7	27,6	27,4
ROOM 8	TU 8	27,4	27,6	27,3	27,2	28,3	27,3	27,5	27,9	27,5	27,3
AVERAGE		27,4	27,6	27,1	26,7	27,7	27,2	27,3	27,4	27,2	27,2
THERMAL COMFORT LEVEL ON 2ND MODEL ON 3RD FLOOR											
ROOMS	MEASURING POINT	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
ROOM 1	TU 1	27	26,6	27,3	26,2	28,2	26,7	27,5	27	26,6	26,5
ROOM 2	TU 2	27,7	27,6	27,1	26,4	27,3	26,8	27	27,1	26,7	26,8
ROOM 3	TU 3	27,3	27,7	26,4	26,4	27,3	26,8	26,7	27,2	26,9	26,8
ROOM 4	TU 4	27,2	27,8	27,5	26,7	27,5	26,9	26,8	27,4	26,8	27
ROOM 5	TU 5	28,2	27,6	26,9	26,7	27	26,7	27,2	27,5	27,3	27,2
ROOM 6	TU 6	27	27,3	26,8	26,8	27,5	27,2	27,4	27,5	26,8	27,5
ROOM 7	TU 7	27,5	28	27	27,1	27,9	27,5	26,8	27,5	27,4	27,3
ROOM 8	TU 8	27	27,3	27,3	26,8	28,2	27,3	27,5	27,8	27,4	27,1
AVERAGE		27,4	27,5	27,0	26,6	27,6	27,0	27,1	27,4	27,0	27,0

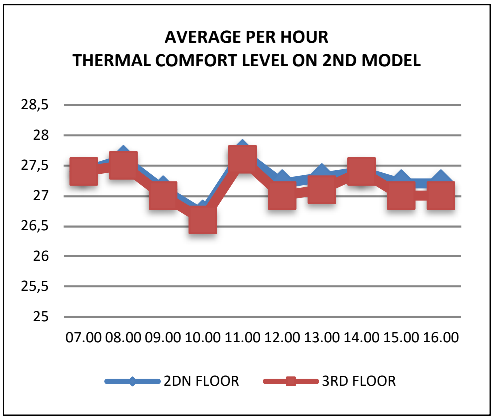

Figure 9. Graph of Average Per Hour of Second Model Thermal Comfort

The effective temperature in the first model analysis tends to be lower than the second model due to air movement, which affects the high and low effective temperature, (Georg, 1994) in the first model analysis fluctuates according to field data while in the second model analysis, the air movement is the same, namely 0.1 m / sec. The lowest average effective temperature per hour on the 2nd Floor has the same value as the 3rd Floor, and the highest average effective temperature per hour on the 2nd Floor is 0.1 ° C TE higher than the 3rd Floor.

The results of the thermal comfort analysis of the first and second models show that both models have an effective temperature in the warm comfort category and the heat category in the Mom-Weiseborn thermal comfort standard (Soegijanto, 1998). The analysis of the effective temperature of the measuring point of the second model is in the category of heat more than the analysis of the first model. This condition is due to the constant air movement in the second model at 0.1 m/s, below the first model, which has a movement of 0.15-0.24m /s.

4 CONCLUSIONS

The movement of air in the classroom on the 2nd and 3rd Floors is included in the criteria for comfortable air movement. The air movement in the classroom on the 3rd Floor is higher than on the 2nd Floor. The water vapour content in the air in the morning is higher than in the afternoon, causing the humidity of the 2nd Floor and 3rd Floor to be high in the morning, then it tends to fall into the afternoon. The water vapour content is high in the morning because the heat of solar radiation received at that time is still low. The dry temperature for both the second and third floors is low in the morning and then rises until the afternoon. The dry temperature of the 2nd-floor classrooms tends to be lower than the 3rd-floor classrooms. This condition is due to the higher elevation of the 3rd Floor classrooms to receive longer solar radiation heat. Heat enters the room through the conduction process, namely through walls and roofs and through the process of solar radiation transmitted through windows.

The effective temperature on the 3rd Floor is lower than the 2nd Floor because of the location of the 3rd-floor classrooms, which is higher than the 2nd Floor. This condition allows the movement of wind entering the classroom to get a minor obstacle factor, such as other buildings and surrounding trees. The movement of air that enters the classroom 3rd-floor classroom is higher than the 2nd Floor.

The results of the thermal comfort analysis of the first and second models show that both models have an effective temperature in the warm comfort category and the hot category in the Mom-Weiseborn thermal comfort standard. Analysis of the effective temperature of the measuring point of the second model is in the hot category more than the analysis of the first model. This condition is due to the constant air movement in the second model at 0.1 m /s, below the first model, which has a movement of 0.15-0.24m/s. In the analysis of the first and second models, air movement in the room needs to be increased to optimize natural ventilation in the room. A fan can be applied so that the effective temperature of the room is included in the criteria for optimal comfort according to Mom-Wiesebron standards.

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