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Assessing Thermal Comfort Parameters in Public School Buildings for Tropical Areas

A Study of Teacher's Lounge of SDN 27 in North Pontianak

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Abstract – The thermal comfort of the teacher's lounge at the Public School Buildings of SDN 27 in North Pontianak is an important factor in providing room conditions to support the activities of teaching staff. Thermally, comfortable conditions play a role in increasing the productivity of teaching staff. However, the thermal condition of the teacher's lounge at SDN 27 in Northest Pontianak does not meet the thermal comfort standards. Based on the facts, the thermal condition needs to be solved to achieve comforts in teacher's lounge. Formulation of indicators for thermal comfort conditions was conducted in this research with CFD simulation. A seven-day research process obtained on the observation of thermal comfort levels in the teacher's lounge. The modeling of the software includes indicators for adding heat loads under the roof and changing the wall paint color to beige. Both indicators can reduce the room temperature by 9.4 °C. In addition, changing the opening and applying cross ventilation are also indicators that the teacher's lounge achieves a comfortable, thermally neutral condition. The final result of this study is that a teacher's lounge has a 0.26 value of thermal comfort, and the room conditions have a neutral thermal sensation value.

Keywords: *building performance, computational fluid dynamics (CFD), indoor thermal quality, thermal comfort assessment.*

I. Introduction

Thermal comfort in a room is an aspect that affects the success of a building. Thermal comfort is a feeling of comfortable condition that influences people and it affects a person's productivity (Sativa & Adilline, 2021). Thermal comfort requirements can only be felt during activities by human beings with a healthy body condition. The thermal comfort marked by each individual can be different from one another (Wang et al., 2018). However, generally, these differences will remain within the value of the same thermal sensation. Aspects of thermal comfort need to be applied in expansion designing, both for residential houses and public buildings. A public building, as an example is a elementary school, needs to be designed according to thermal comfort requirements.

Public school construction in Indonesia generally does not evaluate the level of thermal comfort for daily activities in academics (Gunawan & Ananda, 2017). Schools are built only with the aim of being a place of learning, with some designed spaces to support the success of an education. The problems related to thermal comfort are not only considered in the design of building construction. In the case of buildings, the increase in thermal comfort costs in tandem with rising energy prices is noticeably greater (Raimundo & Oliveira, 2022). Generally, the achieved level of thermal comfort in public school buildings will be resolved by the use of artificial ventilation. Prakash and Ravikumar (2015) mentioned that to maintain enough ventilation is one way to ensure indoor thermal comfort; however, this depends on a number of variables, including wind speed, outside temperature, building topography, surrounding height, form, and orientation, as well as the kind, size, and location of window openings. Commonly found in construction, many public schools generally apply natural ventilation for air circulation (Wardhana & Iyati, 2018). Most public elementary schools in Pontianak City still use a natural ventilation system that utilizes the climatic conditions around the school environment (Saputra, 2020). The perimeter of the public school for the general room has a lower airflow rate than the center. Air movement provides the room with steady air change and even air circulation. The rate at which outside air is swapped for and replenished with fresh air depends on the wind speed (Monica et al., 2022b). This study is a beneficial effort to achieve thermal comfort inside rooms even though the school building uses a natural air conditioning system.

One of the public elementary schools in Pontianak City that uses natural ventilation is SDN 27 in North Pontianak. This public school building, which is established by the city government, has several spaces that are used to support activities in the school. The design of this public building is commonly constructed according to the Ministry Guidelines for Elementary Schools. According to the guidelines, the design will follow the number of needed spaces for academic activities without any awareness of the comfortability of the users. An example is the teacher's lounge, which becomes an office for teaching staff. A comfortable teacher lounge plays a role in the productivity level of teaching staff. This is a factor in the success of the teaching and learning process in schools, which is, of course, balanced with the ability of the teaching staff to manage student learning activities (Fitrianawati & Kurniawan, 2020). Thermally, uncomfortable room conditions can make its occupants dizzy (Sari et al., 2022). Other symptoms of an uncomfortable room are dehydration, stuffiness, and loss of concentration.

The teacher's lounge of the SDN 27 North Pontianak does not have good air circulation, and the level of thermal comfort exceeds the neutral thermal comfort limit. Under certain circumstances, the room's airflow is shaped like a straight line. Because of the straight-line arrangement, air will swiftly enter the space through the inlet ports and escape through the outlet apertures. The air circulation pattern is nearly constant across the room (Monica et al., 2022b). The inability to achieve thermal comfort in the teacher's lounge is attributed to elevated air and radiation temperatures both inside and outside the room. In addition, wind speed and air humidity also affect the level of thermal comfort in the teacher's lounge. Sangkertadi and Syafriny (2016) advised that buildings in tropical and humid locations need to be provided with architectural devices, such as electrical fans and efficient linked shading mechanisms, to prevent excessive mean radiant temperature and to maintain the ideal wind speed. These two thermal comfort factors are climatic circumstances, and those are also difficult to control. Based on visual observation, the teacher's lounge is applying features to adjust to a thermally comfortable condition. Some apply several indicators that can indicate a condition in the teacher's lounge, trying to apply features for its thermal comfort. The thermal comfort of the room needs to be created because this situation has a direct impact on the teaching staff who are doing academic activities in the room during working days.

II. METHODOLOGY

This study took place in the teacher's lounge of SDN 27 in North Pontianak (see Fig. 1). The teacher's lounge has a capacity for 10 teaching staff. Data measurement in this research was carried out for seven days during March 2022, which is the peak of the sun's culmination. The days used as samples for data collection are the days before the culmination on March 10, 15, and 17, 2022; the day when the sun peaks is March 21, 2022; and the day after the peak solar culmination is March 22, 23, and March 25, 2022 (Monica et al., 2022a). The data measured in this research are air temperature values, radiation temperature values, wind speed levels, and indoor air humidity values. Research has generated data limitations related to the building's construction and climate circumstances without conducting direct interviews with existing users. The primary data are continuously developed as a basis for analysis and design recommendations for future adaptive reuse buildings. Using data obtained from these measurements, a singular dataset is selected as a reference for the room condition with the highest level of thermal comfort. This dataset serves as a benchmark for establishing indicators to attain a neutral level of thermal comfort in the room.

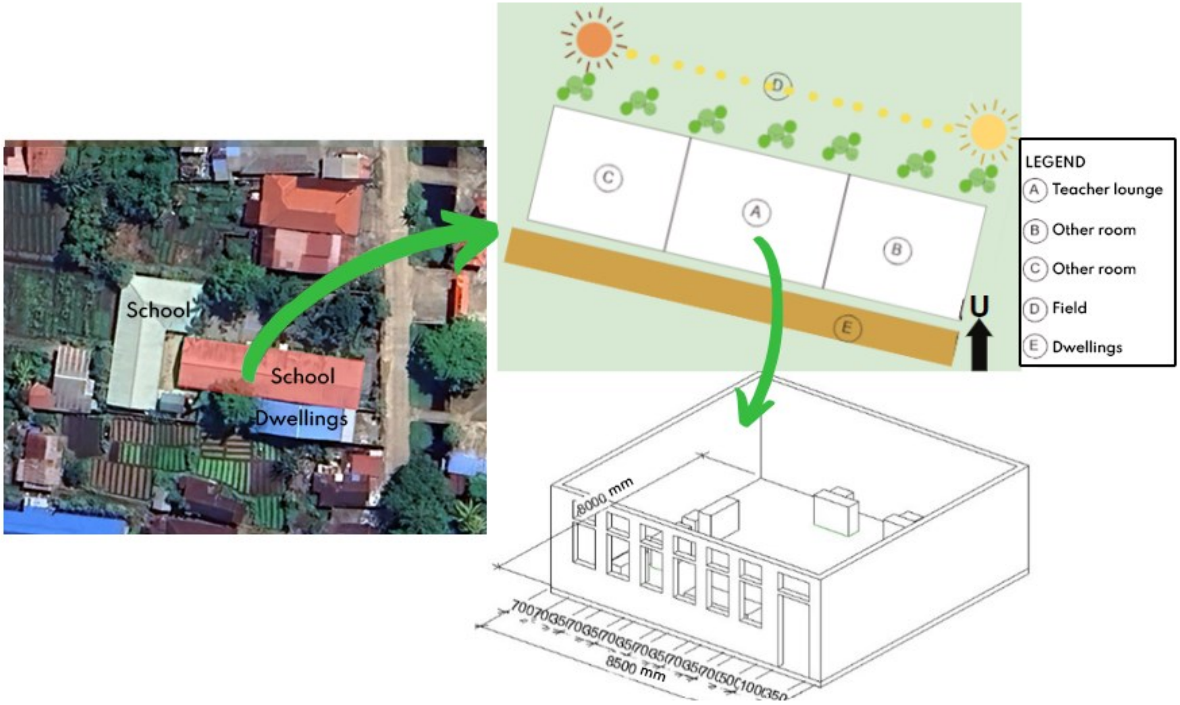

Fig. 1. Object of Research
Source: Authors (2023)

The assessment of thermal comfort in this study utilized the Predicted Mean Vote (PMV) method. The result of the PMV is seven points of thermal sensation value (Dede, 2019). The thermal sensation values are cold (-3), cool (-2), slightly cool (-1) neutral (0), slightly warm (+1), warm (+2) and hot (+3). The level of thermal comfort is comfortable if it is in a neutral zone (Delyuzir & Murni, 2019). This study will conduct an assessment of thermal comfort referring to the numbers in the PMV.

This research utilized Computational Fluid Dynamics (CFD) simulation software to get a three-dimensional model of comfortable thermal conditions. CFD simulation can describe the thermal conditions of the original room conditions and the room conditions as changes result to achieve thermal comfort conditions. This software is used to manage measurement data by adding information related to room sizes, factors that affect thermal comfort, building materials used, and the direction of wind movement in and out of the room (Latif et al., 2016). Changing room to achieve thermal comfort are carried out by adding materials, changing openings, and changing paint on the walls of the teacher's activity room at SDN 27 in North Pontianak. The following is the equation used to obtain the thermal comfort indicator of space:

$$U = 1 / (1/f_o + R_b + 1//f_o) \quad \text{(i)}$$

$$Q_c = A . U . \Delta T \quad \text{(ii)}$$

$$\Delta T = f_o . T_i \quad \text{(iii)}$$

$$N = H / 0.33 . V . (t_1 - t_0) \quad \text{(iv)}$$

$$Q = V.N/3600 \quad \text{(v)}$$

$$Q = C_v \cdot A \cdot C_{v(multiplier)} \cdot v \quad \text{(vi)}$$

III. RESULTS AND DISCUSSION

The highest level of thermal comfort in the teacher's lounge is 2.80. This score describes that the condition of the teacher's lounge has a hot thermal sensation. The teacher's lounge does not reach a comfortable thermal condition because the air temperature and room radiation temperature are too high. The high air temperature factor causes an increase in the value of the thermal sensation of the room (Pratama, 2021). The air temperature in the room is 33.7 °C, and the humidity value is 57.7%. The room temperature is high due to the hot and scorching weather around the school environment. According to Lala and Hagishima (2023), warm and intense temperatures highlight how humans' susceptibility to heat exposure can affect their health, including the manifestation of physical signs of heat exhaustion. This condition is exacerbated by low air movement in the room. The high level of thermal comfort value makes the room have to undergo several changes so that the room can have a neutral level of thermal comfort. The change was made because the teacher's lounge still uses natural ventilation.

Changes are made to achieve thermal comfort by taking into account the factors of air temperature, radiation temperature, and wind speed (Shafa & Sari, 2022). These three factors are important because they are included in climates that affect the value of thermal comfort based on the PMV standard (Fidela, 2019). The value of the radiation temperature can be reduced by adding heat-resistant material in the form of double-sided aluminum foil bubble at the bottom of the roof covering (Dien et al., 2021). The decrease in the value of radiation temperature is proportional to the decrease in the air temperature value. It can be concluded that the addition of a heat retainer will also make the air temperature in the room decrease. In addition to heat-retaining materials, wall areas that are directly exposed to solar radiation will be coated with wall paint. In discussing the impacts of body temperature in a hot environment, Rahma et al. (2020) mentioned that the weak group includes the relationship between blood pressure and body temperature in a hot workplace, which has a positive orientation and alters the physiological response of the body.

Wall paint with a low absorption value affects the absorption of radiation from the outer walls to the interior walls (Wahyudi et al., 2018). Bright or lighter wall paint colors have a lower absorption value than dark wall paint colors such as dark green, dark blue, and black (Chairi, 2019). This study provides an indicator by changing the existing wall paint color, which is dark green ($\alpha = 0.88$) to cream ($\alpha = 0.3$). Calculations were carried out to obtain the value of the temperature change due to changing the color of the wall paint by using equation 1 to get a result of 6.53 W/m^3 °C. Abdullah and Faraj (2022) mentioned that the value of the temperature change due to changing the color of the painted wall was approximately equally difference in the external and internal temperatures. These results were then calculated using equation 2 and got a result of 1.4 °C. Based on these formulas, it is known that the air temperature value decreased by 1.4 °C as a result of the change of dark green wall paint ($\alpha = 0.88$) to cream ($\alpha = 0.3$). The application of this indicator still does not meet the value of thermal comfort because the air temperature in the teacher's lounge is still below the thermal discomfort value of 32.3 °C. Furthermore, other indicators are needed to achieve a comfortable thermal room condition. The next indicator to be considered to achieve thermal comfort inside the teacher's lounge is the use of a heat-resistant coating under the roof of the teacher's lounge.

Calculations to determine changes in the value of indoor air temperature due to the addition of aluminum foil bubble double sides using equation 3. Wang et al. (2017) and Zhu and Wang (2020), stated that bubble with more volume is more efficient in improving properties of the composite and a positive effect on the thermal insulation. The results of these calculations show that there is a decrease in room temperature of 8 °C. This condition certainly makes the temperature in the teacher's lounge already within the thermally comfortable air temperature range of 24.3 °C. The addition of a heat-resistant coating provides a high air temperature reduction effect. According to the testing findings of Guo et al. (2012), the heat-reflective insulating coating could successfully lower the temperature of the outside wall surface. The total decrease in indoor air temperature due to the addition of heat-retaining material in the form of double-sided aluminum foil bubble and the change of dark green wall paint color to cream is 9.4 °C. According to Shen et al. (2011), reflective coatings can significantly reduce exterior and interior surface temperatures by using different coatings, with the maximum reduction in many possibilities of mean radiant temperature. The impact of reflective coatings on indoor environment and building energy consumption depends on the location, season, and orientation of the building. By using heat-retaining material, the thermal conditions will resolve the problem of high air and radiation temperatures inside the teacher's lounge. However, another problem that will arise is that the condition of the room will become stuffy and make the teaching staff cramped and hot.

The value of heat absorbed is less making the value of the air temperature decreases. The level of thermal comfort will be achieved in these conditions. However, to create comfortable and not stuffy room conditions, good air circulation is needed (Rahmat et al., 2020). An alternative to creating air circulation in space is to maximize the movement of the surrounding air. This action can spread evenly across all points in the space (Ginting, 2021). As per the suggestion for design, the opening point is lower than the outlet. This change is made with the consideration that air will move from areas of high pressure to areas of low pressure. According to Chu et al. (2015), adding one opening can dramatically raise the air change rate. The location, size, and external wind speed had no bearing on the dimension-less exchange rate of shear ventilation. However, there is a linear correlation between the wind speed and opening area and the air change rate. The location of the ventilation above the window compared to the location of the ventilation below the window has lower air pressure. Ventilation placed at the bottom gives the effect of wind entering the room more quickly and can exit through outlet openings that are located higher. Based on this explanation, the wind should be able to reach all points in the room, and this condition certainly has an effect on the level of thermal comfort.

Openings in the teacher’s lounge have two functions: inlet openings and outlet openings. This space only has one side for access to the air circulation in and out. The use of openings with dual functions is called a one-sided opening (Latif, 2020). The use of one-sided openings is less effective for the teacher’s lounge because the amount of air that enters is not proportional to the number of activity occupants. This condition can cause the room to become stuffy because the teacher’s lounge uses a natural ventilation system that depends on the rate of air flow that enters the room. The size of the openings for the activities of the teachers at SDN 27 in North Pontianak is described in Table 1. The lounge for the teachers at SDN 27 in North Pontianak has three types of openings that are divided into doors, windows, and/or ventilation at the top of the windows and doors. The shape design of all the openings in the teacher's lounge is found as a rectangle with a lined position.

Table 1. Teacher’s Lounge Opening Size in SDN 27 North Pontianak

Opening	**Inlet opening**	**Outlet opening**
Door	2 m * 1 m (1 door)	2 m * 1 m (1 door)
Window	0.9 m * 0.7 m (6 windows)	0.9 m * 0.7 m (6 windows)
Ventilation	0.5 m * 0.7 m (6 ventilations); 0.5 m * 1 m (1 ventilation)	0.5 m * 0.7 m (6 ventilations); 0.5 m * 1 m (1 ventilation)

Source: Authors (2023)

Based on the CFD simulation, it can be seen that the air movement in the room is asymmetric. The visible wind color indicator is dominated by blue on the side of the wall that is far from the opening. This condition can be interpreted as indicating that the movement of air in space is irregular. Under the conditions in the environment, a wind speed value of 0.25 m/s cannot reach all corners of the room. However, the area near the side of the opening has air movements ranging from 0.1 m/s to 0.25 m/s. This condition has met the recommended wind speed standards. However, the room has a high temperature value and is not proportional to the wind speed in the room to be able to achieve a comfortable thermal condition.

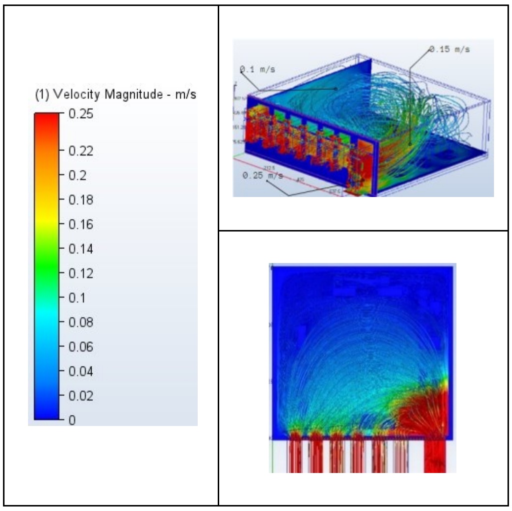

Fig. 2. Air Flow in Teacher's Activity Room in SDN 27 North Pontianak
Source: Authors (2023)

A brief description can be added as per the room condition using CFD simulation, which was also carried out to determine the value of the PMV in the teacher's lounge (see Fig. 2). The results of the simulation that was carried out in the teacher's lounge on March 23, 2022, showed that the room had a PMV value above 2.5 (see Fig. 3). This condition is certainly beyond the recommended thermal comfort limits. Based on this, the opening of the room must be changed so that the wind can enter according to the needs of the space. According to Wang et al. (2020), optimal conditions for wind energy exploitation are defined as average wind velocity values greater than 3 m/s for each intake direction. Before being able to determine the change in openings to meet thermal comfort, calculations are needed to determine the value of the wind speed required for the space to reach the comfort point. The calculation of the need for air flow in the room under certain temperature conditions and calculating the required opening area to maximize the movement of air flow can use equation 4 and continue with equations 5 and 6. The results of these calculations show that the teacher's lounge requires 4 m^2 for inlet opening and outlet opening.

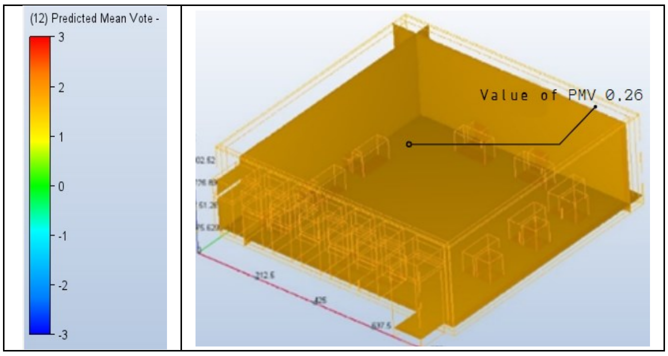

Fig. 3. PMV Level of Thermal Comfort in Teacher's Lounge in SDN 27 North Pontianak
Source: Authors (2023)

the estimation describes that the airflow requirement for the teacher's lounge is 0.27 m^3/s. The ventilation system that will be used in the teacher's lounge indicator is a type of cross ventilation. Cross ventilation was chosen because it is effective and efficient in the utilization of natural ventilation for the room (Mufidah et al., 2021). In addition, the use of cross ventilation is also more environmentally friendly (Razak & Wulandari, 2020). The following is the size of the teacher's lounge openings that have been calculated based on the need for airflow discharge (see Table 2). The application of this type of opening is available in Figure 4. The teacher's lounge opening is added to the front side of the initial opening so that it becomes cross-ventilation.

Table 2. Teacher's Lounge Size in SDN 27 North Pontianak After Application of Thermal Comfort Parameters

Opening	**Inlet opening**	**Outlet opening**
door	2 m * 0.9 m (1 door)	-
window	-	0.7 m * 0.7 m (6 windows)
ventilation	0.45 m * 0.8 m (5 ventilations), 0.4 m * 0.9 m (1 ventilation)	0.25 m * 0.7 m (6 ventilations)

Source: Authors (2023)

Changing the opening design of the teacher's lounge by adding more openings is expected to increase the advantage by allowing more air to enter the room. The required air clearance is related to maximizing the level of wind speed entering the room. The placement of the teacher's lounge openings considers the difference in air pressure so that air can enter the room without any obstacle through the designed inlet. In addition to paying attention to the air circulation factor, the placement of openings in the new design also has the intention of enhancing the architectural value of the openings so that the activities of teachers in the lounge will be protected from outside observation. By this design, it is managed so that the teaching staff activities inside the lounge can fully concentrate on duties and will not be disturbed by other outside-room activities in the school building.

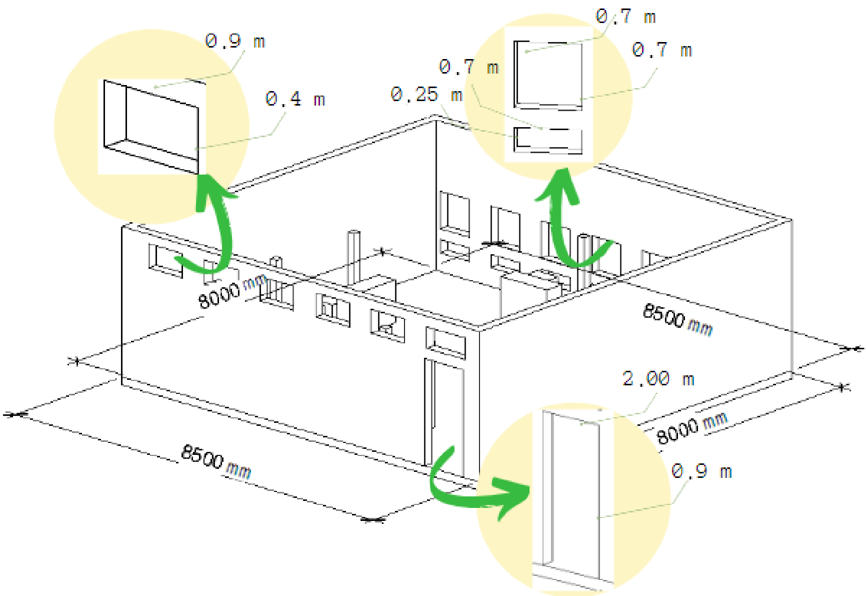

Fig. 4. Application of Room Openings in Teacher's Lounge in SDN 27 North Pontianak
Source: Authors (2023)

The CFD simulation with the changes that have been made shows that the air movement in the room is dominated by a green indicator, which means that the wind speed is within a comfortable range of 0.12 m/s to 0.15 m/s (see Fig. 5). The red indicator is visible at several points in the room close to the opening. Wind speed values are close to the opening range of 0.18 m/s to 0.25 m/s. The teacher's activity room, after the application of cross ventilation, no longer has a blue wind movement indicator section like in its initial condition. The changes and additions to the openings have made the air flow reach all points in the teacher's lounge.

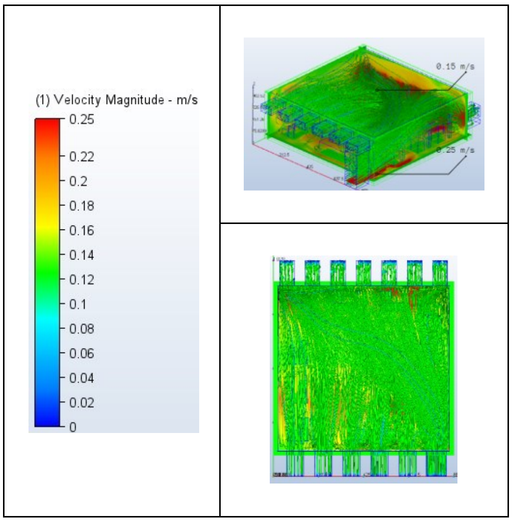

Fig. 5. Airflow Simulation After Application Openings in Teacher's Lounge in SDN 27 North Pontianak
Source: Authors (2023)

The current state description of the condition of the room with the openings that have been changed using CFD simulation is carried out to determine the PMV or thermal comfort value (see Fig. 6). Changes in the size of the openings have made the teacher's lounge reach a neutral level of thermal comfort. Wind speed is also almost evenly distributed at all points in the space. The PMV for the teacher's lounge has changed from those above 2.5 to 0.26. This change is an amalgamation of three indicators that have been applied in three-dimensional modeling.

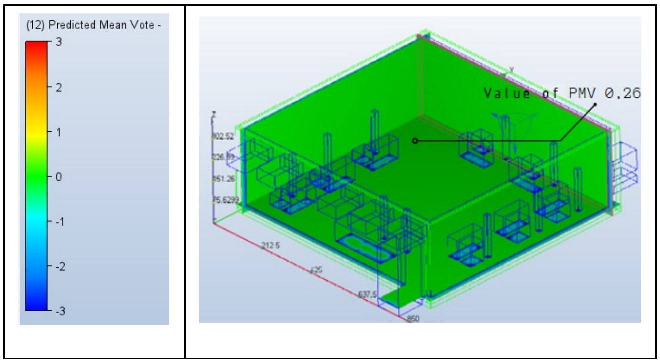

Fig. 6. PMV Level of Thermal Comfort in Teacher's Lounge in SDN 27 North Pontianak After Application Thermal Comfort Parameter
Source: Authors (2023)

IV. CONCLUSION

Thermal comfort is an important aspect and also influences the success of an architectural design as well as on the level of efficiency in the use of space by actors. Based on the research that has been done in the building for the teacher's activities of the SDN 27 in North Pontianak. It can be concluded that the room in the building is uncomfortable. The highest level of thermal comfort in the teacher's lounge is 2.80. The indicator is given so that the teacher's lounge reaches a comfortable neutral thermal condition or with a thermal comfort value of -0.5 to 0.5. The indicators provided are in the form of changing the openings according to the needs of the air flow rate required for the teacher's activity room; application of cross ventilation; color cream (= 0.3); as well as the addition of double-sided aluminum foil bubble 4 mm at the bottom of the roof covering. The addition of heat-resistant material and the change of wall paint with a lower absorption value has reduced the room temperature by 9.4 °C. The addition of openings and the application of cross ventilation also makes the air circulation in the room more stable with even distribution of wind at all points in the teacher's lounge. Changes in the application of the three indicators of achieving thermal comfort in the room as a whole experienced a change in the PMV of 2.54. The application of the use of thermal comfort indicators with a sample of the teacher's lounge can be used for similar rooms located in the tropics. However, the surrounding environmental conditions need to be considered in its application. Due to the limitations of the current research, for future research, it is beneficial to conduct in-depth interviews with users to compare the analysis and user needs. The comparison will strengthen the design according to the thermal comfort level and user activities inside the lounge.

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