Indoor Thermal Condition of Passive Cooling System at Student's Dormitory of Universitas Hasanuddin FoE Campus

by Nurul Jamala

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Abstract. A dormitory is a simple building that is intended as a residence for students. Universitas Hasanuddin, Faculty of Engineering (FoE), has a student dormitory very close to the FoE campus. The purpose of this study was to determine the indoor thermal conditions of the rooms in the dormitory. Furthermore, how the environment affects thermal comfort in the building. The research method is a quantitative method based on descriptive statistics on measurement results in the selected space and the data simulation using the Ecotect software. The results of the study concluded that the dormitory had not met the standard of thermal comfort in Indonesia, the average temperature was above 30°C. The simulation results of improvements concluded that the change in ceiling height could significantly reduce the temperature.

INTRODUCTION

Universitas Hasanuddin - Faculty of Engineering (FoE) Campus, which has been used since 2012, is equipped with various facilities, ranging from lecture facilities to dormitory facilities for students. The student dormitories are divided into dormitories for male students and dormitories for female students as well. The dormitory of male students is located in front of the campus, as can be seen in Fig. 1.

The dormitory for male students was constructed around 2017 and began to be used in 2019. This dormitory consists of 11 residential blocks and is still in the campus environment. Each residential block consists of 10 room units and one service unit (public bathrooms and toilets). Furthermore, each room unit is occupied by two students.

Cooling in buildings is the most considered aspect in tropical climates. This condition is exacerbated by the heat gain on the roof of the building which can reach 70% of the total heat gain in the building. The passive cooling method is one of the innovative technological practices that allow buildings to feel comfortable in a natural way. Reflective and radiative processes are one of the methods used to reduce heat gain by facilitating the removal of excess heat in the building interior. Given that the potential of these techniques varies from region to region, furthermore, their application in the tropics needs to be investigated [1]. Around 6.7% of global energy demand is used for thermal management in buildings. As estimated, at least 35% of the building's total energy needs can be met by using alternative resources [2]. The total world energy demand can be reduced by 2.35% with an additional cost of around 15% of the total construction and planning costs [3]. The passive cooling design is used as a cost and resource-effective method to achieve a natural harmony between climate, architecture, and people [4].

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FIGURE 1. Universitas Hasanuddin-FoE Campus area and male students' dormitory location

Passive cooling design strategies are related to various aspects of a building such as size, orientation, shape, location, and layout/mass layout. The impact is easily seen on the energy use performance of buildings. This happens because the mass and layout of the building can produce its shadow effect and can also improve ventilation and natural lighting performance. At almost no additional cost in adapting design strategies such as building orientation, we can achieve significantly beneficial effects on the thermal performance of buildings. Depecker et al. examined the relationship between the shape coefficient and heating load. The study revealed that the heating load in cold climatic conditions is directly proportional to the shape coefficient, the reason being that solar radiation passing through the glass is low. This study also suggests that opaque walls have no relationship with heating loads or shape coefficients, so they are less important in mild and sunny climatic conditions [5]. Stevanović reviewed the flow of heat across the building envelope and revealed that the optimal building shape can reduce heating loads by up to 12% per total building volume [6].

Aldawoud discussed various atrial geometries for energy-saving performance and concluded that a square atrium performed best. The results also show that more energy savings can be achieved in low-rise structures with an atrium that has a greater glass to roof ratio for temperate and cold climatic conditions. However, for hot and dry climatic conditions, a tall structure with a low glass to roof ratio is preferred [7]. Algorithms based on self-shading building envelopes for reduced cooling and lighting loads integrated with different types of facades, glass, orientations, shapes, and life cycle costs have been developed by Capeluto [8] and also has been done by Tuhus-Dubrow & Krarti [9]. Square shapes give better results for all types of climates. Stevanović discussed that a separate unit placed in a curved road configuration required a large amount of heating and cooling when compared to mounted units which were placed in a straight layout [6]. Lastly, it can save up to 30% cooling requirements and 50% heating. Energy savings of 1-5% can be achieved simply by changing the orientation, aspect ratio, and form factor [10,11].

This research aims to analyze the performance of the passive cooling system in the male student dormitory building, FoE Campus of Universitas Hasanuddin. Analysis of passive cooling in the Student Dormitory building is important because in addition to the building being designed to utilize natural ventilation for cooling, it is also important to analyze the performance of wall openings (windows), and the composition of wall materials to achieve comfortable conditions for residents. Therefore, this paper will discuss the effect of building envelope design as a passive cooling technique.

METHOD

A computer simulation was done using Ecotect software to simulate the indoor conditions of the student's dormitory of FoE Campus. The simulation was intended to figure out the indoor temperature condition of the building.

Ecotect is an analysis software that integrates 3D modeling with various analyses and simulations of building performance. Various interactive analysis and simulation features, so that any changes to the design will have an impact on building performance. The simulations that Ecotect can perform include: sun-shading, natural & artificial lighting, overall thermal transfer, mean radiant temperature, heat island, thermal comfort period, cooling load, and energy-efficient index). The simulation results will be seen in the form of grid analysis, table, including graphs.

Ecotect software is a significant choice in a bioclimatic approach to make it easier to implement because this software has some user-friendly bioclimatic simulation features. Ecotect can generate a building performance analysis, the analysis results can be considered earlier at the conceptual stage than at the end of the design process, thus saving time.

Mass Layout

The location of the research object is the Hasanuddin University Faculty of Engineering Male-Student Dormitory which is located on the Malino km. 6 Bontomarannu, Gowa Regency. This dormitory complex has 10 buildings, one building which is still under construction as can be seen in Fig. 2.

FIGURE 2. Universitas Hasanuddin-FoE Campus area and male students' dormitory location

Furthermore, the mass layout of the dormitory complex as simulated in the Ecotect can be seen in Fig. 3. The structure of the building mass in this dormitory complex is a grid pattern where each building is paralleled and has a regular spacing between. The distance between one building and another is 5 m. The buildings have an East orientation in direction. The building in the Student Dormitory has wall material made form of Polyurethane Sandwich Panels. On the roof, this building uses lightweight steel. On the floor, the type of material used is a ceramic floor.

Vegetation elements in this area are mostly located on the left side of the area. However, the vegetation in this area is only in the South and East of building E. The Southside of building C also has vegetation but not as much as on the left side of building E. Because this building functions as a residential building (a place to rest) so at certain hours, from 08:00-16:00 during daytime (especially during the lecture hours) there is no activity in this building. Usually, the activities carried out by students when they are in their respective rooms will mostly choose to rest (45 Watt) or sleep (40 Watt). In general, the residents of this dormitory wear clothes consisting of underwear, short sleeves, and shorts. The total value of the clothing insulation is 0.3 clo.

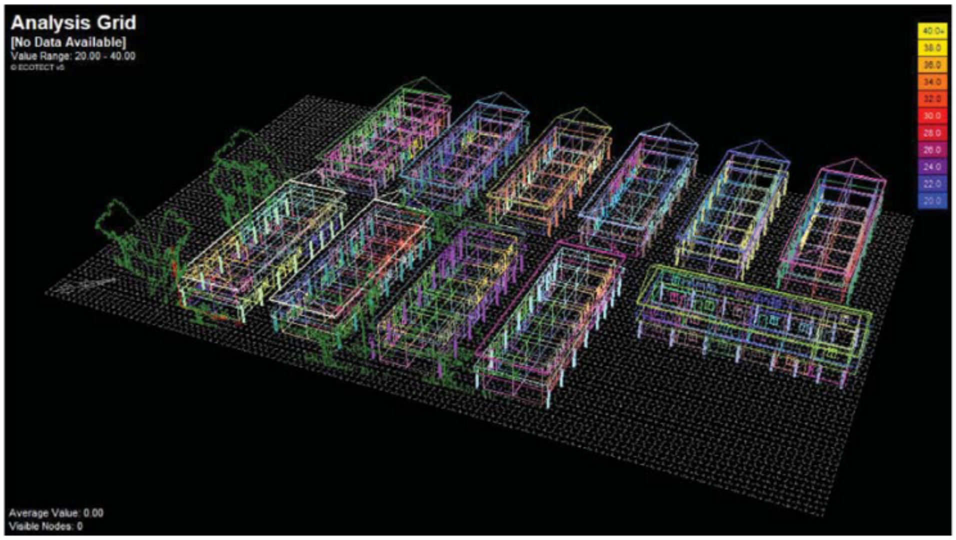


FIGURE 3. Mass layout in Ecotect

The orientation of the 10 dormitory buildings is 45 degrees from the North with the distance between buildings is 5m. One building is orientated to 315 degrees from the North. This boarding area has a site area of approximately ± 1.03 hectares.

Building Construction

The construction of the dormitory buildings is made by a knockdown system. The building consists of two stories of lightweight steel frame construction with the exterior wall is made from framed-board. The roof is framed by lightweight steel and covered by aluminum zinc and insulated by polyurethane sheet. The floor is concrete and covered by tile.

FIGURE 4. The dormitory is 2-storey constructed by lightweight steel frame construction

Building Material

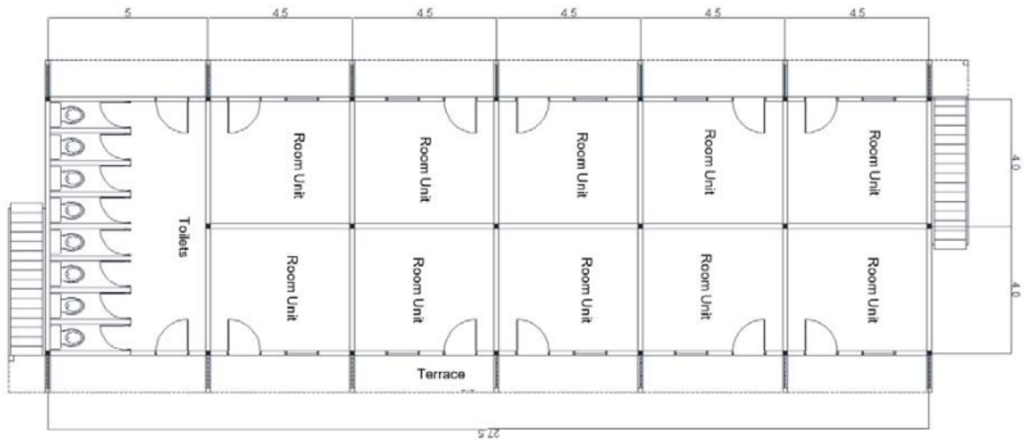
The construction material is prefabricated. The assembly of materials is conducted on-site. Table 1 describes the material properties of the dormitory.

TABLE 1. Building material specifications

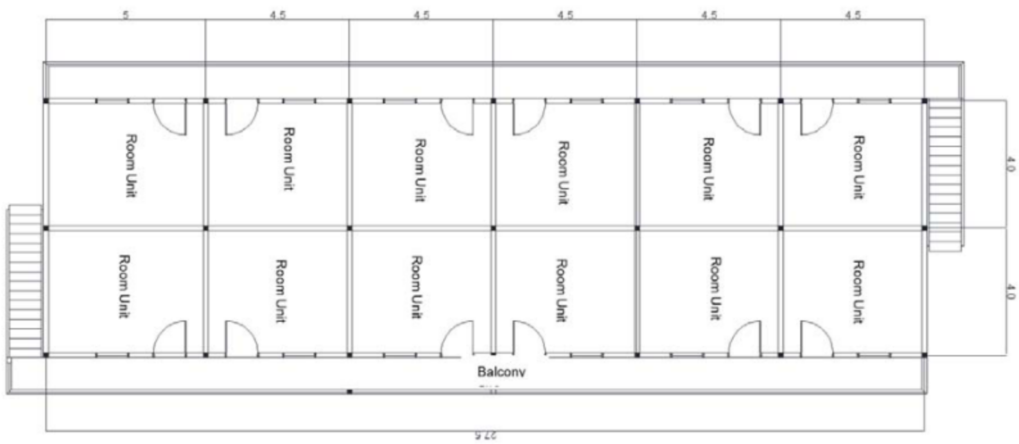
Material	Construction layer	
Roof Metal deck Insulated	Aluminum Alloy (Outside), Polyurethane foam (Insulation)	U-Value = 0.550 [W/m²K] Admittance = 1.000 [W/m²K] Solar absorption (0-1) = 0.5 Transparency (0-1) = 0 Thermal decrement = 0.96 Thermal lag = 0.7 [hrs] Emissivity (0-1) = 0.89
Wall Framed Aluminum Cladd Plasterboard	Aluminum (Outside) Cladding, Polyurethane foam, Aluminum Alloy (Inside)	U-Value = 2.200 [W/m²K] Admittance = 2.200 [W/m²K] Solar absorption (0-1) = 0.4 Transparency (0-1) = 0 Thermal decrement = 1 Thermal lag = 0.3 [hrs] Emissivity (0-1) = 0.9
Ceiling Plaster insulation suspended	Airgap (Outside), Plasterboard (Inside)	U-Value = 0.500 [W/m²K] Admittance = 0.900 [W/m²K] Solar absorption (0-1) = 0.36 Transparency (0-1) = 0 Thermal decrement = 0.32 Thermal lag = 0.7 [hrs] Emissivity (0-1) = 0.9
Floor Concrete slab-on-ground (1st Floor)	Soil (Outside), Concrete, Concrete Screed, Ceramic Tiles (Inside)	U-Value = 0.880 [W/m²K] Admittance = 6.100 [W/m²K] Solar absorption (0-1) = 0.475208 Transparency (0-1) = 0 Thermal decrement = 0.31 Thermal lag = 4.6 [hrs] Emissivity (0-1) = 0.89
Concrete slab-suspended (2nd Floor)	Plasterboard (Outside), Airgap, Concrete, Concrete Screed, Ceramic Tiles (Inside)	U-Value = 2.900 [W/m²K] Admittance = 5.210 [W/m²K] Solar absorption (0-1) = 0.475208 Transparency (0-1) = 0 Thermal decrement = 0.69 Thermal lag = 4.1 [hrs] Emissivity (0-1) = 0. 9

Ventilation and Openings

Ventilation and openings are located in each room, mostly at the front wall of the rooms. Each unit of openings is consisting of a sliding window and ventilation. Ventilation and openings can be seen in Fig. 5.



(a) First floor



(b) Second floor

FIGURE 5. Room layout and ventilations

Building Operation Condition

The building design condition is operated under natural ventilation conditions. Each room is occupied by two students. The comfort band was set to 16°C (lower) and 26°C (Upper). The activity is set to typing sedentary with 65 Watt of met. The clothing (clo) for the occupants/students was assumed short and T-shirt (0.4 clo). The relative humidity was assumed 60% and the wind speed 0.50 m/s. The indoor lighting level was set to 300 lux.

The room was occupied from 16:00 to 07:00 for weekdays, and full-day from 00:00-23:59 on the weekend. The sensible and the latent heat on each room were set to 5 and 4 W/m^2 respectively. The air change rate (ACH) was set to 1.0, and the wind sensitivity was set to 0.5 ACH.

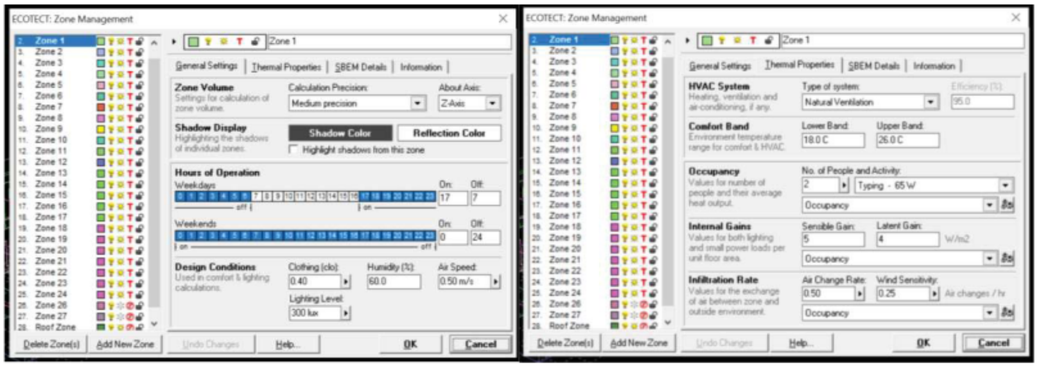


FIGURE 6. Zone management: general setting and thermal properties

RESULTS AND DISCUSSION

Indoor Temperature Profile

Indoor temperature measurement results showed that the temperature in building C did not satisfy the standard of thermal comfort of Indonesian SNI (SNI=Indonesian National Standard). The average temperature in each room is above 30°C. The maximum temperature inside is 34.1°C at 13.00-15.00. These conditions occur at the rooms located on the West and center sides of the 2nd floor. While the lowest air temperature is 30.3°C at 03.00 - 07.00 on the 2nd floor in the East.

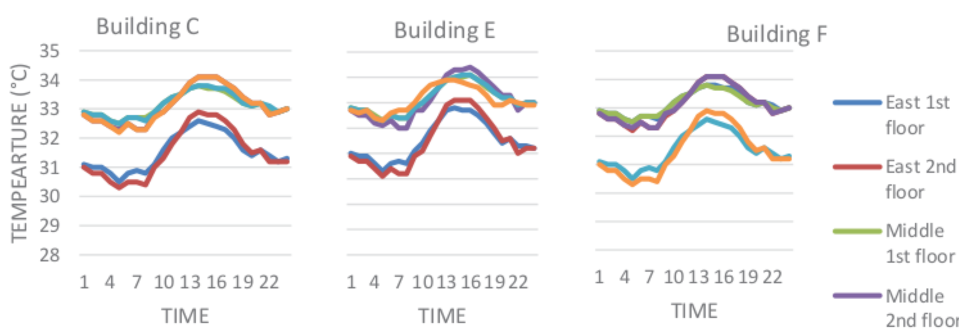


FIGURE 7. The indoor temperature condition of the existing building (Buildings C, E, and F)

Figure 7 shows that the temperature in the rooms located in the East has a lower average temperature than the rooms in the West and the center. This is because on the East corner of the building there is vegetation protecting the side of this building. While on the Westside of the building, there is no vegetation on the side of the building, but it is protected by a building beside it.

The elevation difference also affects the room temperature in the building. The graph shows that rooms on the 2nd floor have the highest temperature and the coldest temperature points compared to rooms on the ground floor. One example is the ratio of the highest temperature between rooms on the Westside of the building. The temperature in the room on the Westside of the 1st floor is 34.3°C while on the second floor it is 34.7°C. The temperature value in building E and this room is not following the standard of thermal comfort. The highest peak of this room temperature is 34.4°C at 15.00 in the Westside located room on the 2nd floor. Meanwhile, the room located on the Eastside of the 2nd floor is the lowest point at 30.1°C at 05.00-06.00 in the morning.

The difference in elevation affects the room temperature in the building. The analysis results show the comparison of the temperature on the second floor in building E which has the highest and lowest temperature points, compared to the room temperature on the 1st floor. An example of a significant comparison is the ratio of the highest temperatures between rooms on the Eastside of the building. The temperature in the room on the Eastside of the 1st floor is 32.8°C while on the Westside room on the 2nd floor is 34.1°C. The temperature at building F does not match the standard of thermal comfort. From the figure, it can be noted that the average temperature of each room is above 30°C. The highest peak of room temperature is 34.1°C at 13.00-15.00 on the Westside of the 2nd floor. The lowest room temperature is 30.3°C at 4.00 am in the room located at the East of the 2nd floor.

Based on the data in the figure above, the temperature in the rooms located in the East has a lower average temperature than the rooms in the West and the center. This is because there is another building protecting the Eastside of this building. Meanwhile, on the Westside of the building, there is no vegetation protecting the side of the building.

The elevation difference also affects the room temperature in the building. The analysis results show that the rooms located on the 2nd floor of building F have a higher temperature point and the coldest temperature point compared to the room on the ground floor of the building. One example of a significant comparison is the ratio of the highest temperatures between rooms on the Eastside of the building. The temperature in the room on the Eastside of the 1st floor is 33°C while on the Eastside room on the 2nd floor is 34.1°C.

Improvement Simulation

Improvement simulation is a building simulation with several changes in the form of several alternatives. In this improvement simulation, 3 factors will be compared namely the ceiling height (changed from 2.75 to 4.0m), the material on the walls (changed from Polyurethane Sandwich Panels to Brick Plaster), and the number of openings (the number of openings has doubled).

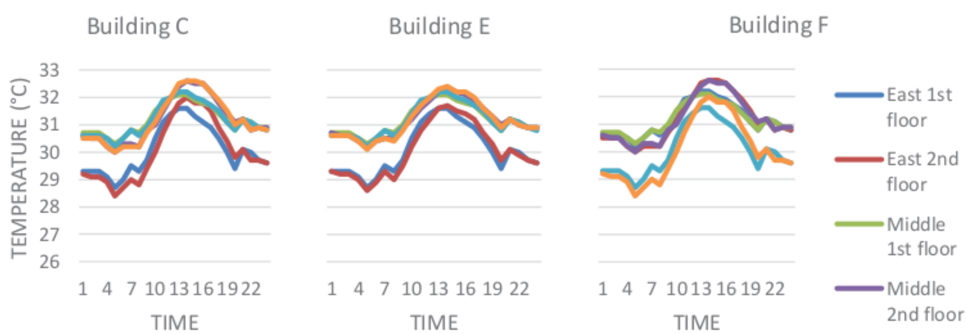


FIGURE 8. The temperature of Building C, E, F - Improvement simulation (ceiling height 4.0m)

As can be seen in Fig. 8, with a ceiling height of 4.0 m room temperature in building C, it has the lowest point of room temperature in this building which is at 28.4°C. As for the highest point, the temperature is 32.6°C. Room temperature in building E has the lowest point of room temperature is at 28.6°C. As for the highest point, the temperature is 32.4°C.

Based on the graph above, it can be seen that with a ceiling height of 4.0m room temperature in building F, it has the lowest point of room temperature in this building which is at 28.4°C. As for the highest point, the temperature is 32.6°C as well.

Based on Fig. 9, it can be seen that by the use of brick plaster material, the room temperature in building C has the lowest point - room temperature in this building which is at 29.9°C. As for the highest point, the temperature is 33.6°C. By the use of brick plaster material, the room temperature in building E has the lowest point which is at 29.6°C. As for the highest point, the temperature is 34.0°C. Furthermore. Based on the graph above, it can be seen that by using brick plaster material, the room temperature in building F has the lowest point of room temperature which is at 29.9°C. As for the highest point, the temperature is 34.0°C.

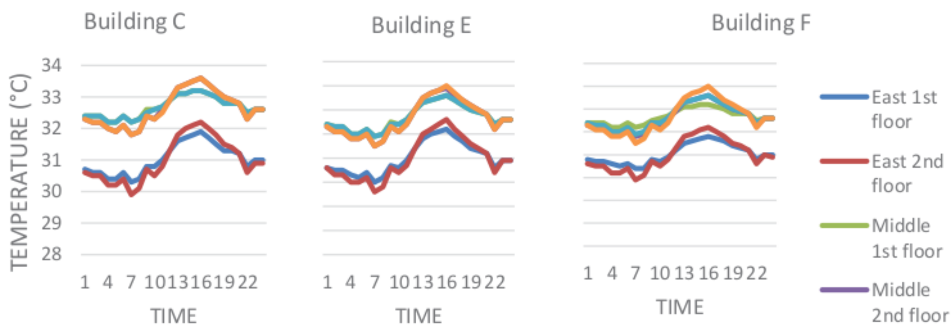


FIGURE 9. The temperature of Building C, E, F – Improvement simulation (material Brick Plaster)

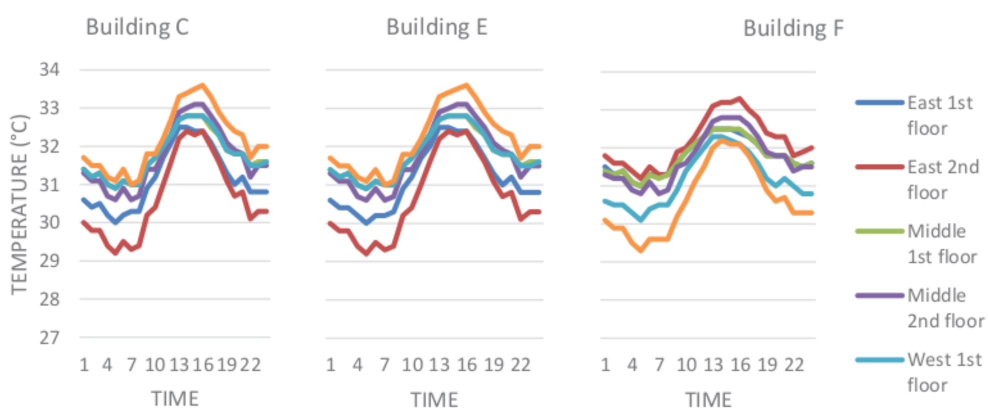


FIGURE 10. The temperature of Building C, E, F - Improvement simulation (more openings)

As can be seen in Fig. 10, by increasing the number of openings 2 times, the room temperature in building C has the lowest point of room temperature in this building which is at 29.2°C. As for the highest point, the temperature is 33.6°C. Furthermore, by increasing the number of openings 2 times, the room temperature in building C has the lowest point of room temperature in this building which is at 29.2°C. As for the highest point, the temperature is 33.6°C. Thus, based on the graph above, it can be seen that by increasing the number of openings 2 times, the room temperature in building C has the lowest point of room temperature in this building which is at 29.3°C. As for the highest point, the temperature is 33.3°C.

The average (mean) daily temperature (N = 24 is a count of 24 hours), that is, the room on the Eastside has an average temperature of 31.5°C. Meanwhile, the rooms on the Westside have an average temperature of 33.1°C. This indicates that the room on the Westside is hotter than the room on the Eastside. Furthermore, the average (mean) daily temperature of building C is that the rooms on the 1st floor have an average temperature of 33.1°C. Meanwhile, the rooms on the second floor have an average temperature of 33.1°C.

The average (mean) temperature for the existing conditions was 32.6°C. As for the improvement conditions with a change in the ceiling height to 4.0 m, which is 30.8°C. Between the Existing condition and the Improvement condition after changing the ceiling height, there is a significant difference. This is because of the Sig. (2-tailed) 0,000 in other words below 0.05.

The average temperature for the existing conditions is 32.5°C. Meanwhile, the improvement condition with the change of the wall material to brick plaster is 32.1°C. This indicates that changing the wall material into brick plaster is one way to get a low temperature, even though the temperature difference is not too large. For a comparison between existing and improvement conditions with the addition of the number of openings, there is a significant difference.

CONCLUSION

The conclusion obtained from this study is that the room temperature in the Hasanuddin University Faculty of Engineering Gowa student dormitory is not following the standard of thermal comfort. The average temperature in each building is above 30°C, while the temperature for comfort standards according to SNI 03-6572-2001 is the highest of 27.1°C. Room orientation is very influential at room temperature. The vegetation and elevation factors are not significant. Among the three improvement simulations that have been carried out, it can be concluded that ceiling height is the most effective factor in reducing the room temperature. Among the significance values of the three improvement simulations, the significance value of the ceiling height is the smallest.

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