Outdoor Thermal Comfort: Application of RayMan Tools

Aisyah Nabilah¹, Lukman Noor Hakim¹, Maulana Calvin Fawzy¹, Try Ramadhan¹

¹Department of Architecture Education, Universitas Pendidikan Indonesia

nabilaha37@upi.edu

Abstract. The UN has issued a policy regarding the achievement of sustainable development goals, among which are to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. One of the contributors to the quality of education is the convenience of buildings as educational facilities. This paper describes thermal comfort analysis in the case study of the LABTEK VII Building on the Bandung Institute of Technology campus divided into 2 cases: the open space in the building's hallway and the study room in the building. Thermal comfort analysis uses standard thermal comfort analysis tools as a measurement effort. This research was conducted by analysing the indicators of thermal comfort in educational buildings with multiple capacities in temperature, humidity (humidity), and wind speed obtained from Meteoblue and indicators of metabolic rate and clothing of building users. The analysis of these indicators is processed using CBe thermal Comfort and Rayman to produce thermal comfort in the building. This paper presents the highest PET values obtained at 2 pm with PET temperatures reaching 40 °C, considered a Hot sensation. And in the CBE measurement results, it can be seen that the process of changing indoor temperature from morning to evening is getting higher. From measurements with these two tools, concludes that the thermal comfort at Labtek VII ITB is thermally comfortable.

Keywords: Thermal comfort; Educational buildings; Psychologically Equivalent Temperature (PET)

1. Introduction

The United Nations has issued a policy on the sustainable achievement of development goals in the form of Sustainable Development Goals (SDGs), which provide 17 goals with 165 targets for a better life, which was endorsed by the 193 UN states. One of the main concentrations in the SDGs is Education because education is an essential part of advancing a country [1]. Education is meant not only for one individual but for the benefit of society. So that education should be the obligation of all elements of society without exception [2]. Education can be a strong foundation in life because it can increase other factors or other goals. The need to ensure quality education that is inclusive and equitable and promotes lifelong learning opportunities for all [3].

According to the United Nations, the quality of education in Indonesia is adjusted to 110 out of 187 countries [4]. So it can be proven that the quality of education in Indonesia is relatively uneven in every region. There is a relationship with the means and infrastructure that become a forum for carrying out educational activities. According to laws of the Republic Indonesia No. 20 of 2003 regarding the National education system, "Every formal and non-formal education unit provides facilities and infrastructure that meet educational needs following the growth and development of physical potential, intellectual, social, emotional intelligence, and the obligations of students" [5]. If viewed based on the
law, it is only natural that the space for education has a comfort state both physically and psychologically. Because basically, every human being in carrying out activities must get a comfort state, which is incredibly comfortable thermally [6]. It turns out that thermal comfort can affect student performance in the classroom [7], because thermal comfort is based on three factors, among others, environmental, individual, and external [4]. The environment's role in thermal comfort can be measured in terms of humidity, temperature, and wind speed. Furthermore, individuals have the body's metabolic system that releases heat with the influence of the activities carried out, including the clothes used.

The choice of site for analysis was LABTEK VII ITB. The building's potential is widely used by students with special needs so that thermal comfort can be a significant factor in this building's comfort. Measurements are made based on simulated thermal comfort factor data using the ASHRAE standard simulated using Rayman to produce PET [8], and CBE Thermal Comfort which results can be PMV, [9] as a basis for analyzing thermal comfort.

2. Literature Review

2.1. PET (Psychologically Equivalent Temperature)

PET is a thermal indicates that shows the temperature perceived by users to determine thermal comfort and microclimate of surrounding outdoor area [10]. Meteorological factors required to calculate PET such as air temperature, air humidity, and velocity in surrounding areas [11]. Users data is also needed to determines human-biometeorology such as gender, age, height, weight, type of clothing and activity [12]. The range of PET as shown in table 1 resourced from the field experiment and measurement of 300 respondents in the hot and humid country Taiwan [13]. Many studies of PET have been carried out in various countries with hot and humid conditions, such as Malaysia and Singapore. By knowing the value of PET, there'll be a solution to achieve thermal comfort in buildings [19].

| Thermal Sensation | PET range for Hot-humid region (°C PET) |
|-------------------|---------------------------------------|
| Very Cold         | < 14                                  |
| Cold              | 14 - 18                               |
| Cool              | 18 - 22                               |
| Slightly Cool     | 22 - 26                               |
| Neutral           | 26 - 30                               |
| Slightly Warm     | 30 - 34                               |
| Warm              | 34 - 38                               |
| Hot               | 38 - 42                               |
| Very Hot          | < 42                                  |

Reference: Liz, Matzarakis, & Hwang, 2010 [4]
3. Methodology
This study was conducted in Labtek VII ITB Porch, Bandung. It is located in -7°33’ and 107°34’ at 766 asl with hot and humid climate characteristic. The chosen user in Labtek VII ITB are women with specific data as described in table 2.

| Sex       | Female                  |
|-----------|-------------------------|
| Height    | 160 cm                  |
| Weight    | 55 kg                   |
| Age       | 20 years old            |
| Occupation| Student                 |
| Clothing  | Islamic clothing (0.8)  |
| Activity  | Outdoor (Labtek VII ITB porch) Standing (70 W) |

The meteorological aspects are carried out with fixed weather stations from Meteoblue. Data collected in July 16th 2020, according to the time use of the porch which used from 7 a.m. up to 5 p.m.

| DATE       | TIME | T (°C) | Rh (%) | V (m/s) |
|------------|------|--------|--------|---------|
| 16/07/2020 | 06.00| 21.7   | 94     | 0.5     |
| 16/07/2020 | 07.00| 22.1   | 93     | 0.3     |
| 16/07/2020 | 08.00| 23.2   | 86     | 1.1     |
| 16/07/2020 | 09.00| 23.5   | 84     | 1.3     |
| 16/07/2020 | 10.00| 24.6   | 79     | 1.3     |
| 16/07/2020 | 11.00| 25.5   | 74     | 1.6     |
| 16/07/2020 | 12.00| 25.3   | 78     | 1.4     |
| 16/07/2020 | 13.00| 25.6   | 78     | 0.9     |
| 16/07/2020 | 14.00| 25.1   | 82     | 0.6     |
| 16/07/2020 | 15.00| 24.9   | 81     | 0.5     |
| 16/07/2020 | 16.00| 24.6   | 83     | 0.4     |
| 16/07/2020 | 17.00| 24.7   | 85     | 0.3     |
| 16/07/2020 | 18.00| 23.4   | 91     | 0.1     |

Reference: meteoblue.com accessed 16/7/2020

4. Findings and Discussion
In the climate aspect, the humidity chart tends to be inversely proportional to the air temperature. The humidity during the day is lower than in the morning, with the highest humidity reaching 94% and the lowest humidity being 74%. The wind chart is also inversely related to temperature. The highest speed is 1.6 m / s at 25.5 °C at 11.00, and the lowest is 0.1m / s at 23.4 °C at 06.00 p.m.
After calculated with RayMan, the results showed that the highest air temperature reached 40.1 °C at 2 p.m. with a Hot perception, and the lowest was 17.1 °C at 06.00 a.m.; with a cold perception. The calculation of PET from meteorological data in ITB shown in figure 4.
Considering users who use the porch at 06.00-08.00 a.m. and 04.00-06.00 p.m., the temperature ranges obtained were at 17 °C to 33.3 °C with a slightly cool perception. This value has categorized as comfortable because the perception value is not too hot and not too cold for the user. Users are less distracted when the PET temperature rises to 40.1 °C during the day because users are less likely to be on porch.

Figure 4. PET graph

5. Conclusion
The study in the educational building ITB gives the understanding of the correlation between microclimate and thermal comfort. The Rayman measurements on Labtek VII ITB porch shows various PET data with 15% of “cool” sensation, 15% of “slightly cool” sensation, 7% of “neutral” sensation, 15% of “slightly warm” sensation, 23% of “warm” sensation, and 23% of “hot” sensation. The highest PET value is at 2 p.m., with PET temperature reaching 40 °C, which has a “hot” sensation. The thermal perception is also an average between “Hot” and “Warm” from 1 p.m. to 3 p.m. when not many users use Porch because at that time most users are studying in the classroom.

This study shows that the atmospheric condition based on geographical location takes an impact on microclimate with the result reach “cool” sensation in the morning, however the PET value tends to get higher in the afternoon due to the built environment in Bandung.

6. Acknowledgement
This article was supported by the Ministry of Research and Technology/National Research and Innovation Agency of Republic Indonesia grant numbers 458/UN40.D/PT/2020 under LPPM Universitas Pendidikan Indonesia.

7. References
[1] A. Matzarakis, F. Rutz and H. Mayer, "Modelling radiation fluxes in simple and complex environments—application of the RayMan model," Int. J Biometeorol, vol. 51, pp. 323-334, 2007

[2] A. Matzarakis and B. Amelung, "Physiological Equivalent Temperature as Indicator for Impacts of Climate Change on Thermal Comfort of Humas," Seasonal Forecasts, Climatic Change and Human Health., pp. 161-172, 2008.

[3] A. Matzarakis and D. Frohlich, "RayMan 1.2.," Meteorological Institute, University Freiburg, 2009. [Online]. Available: https://www.urbanclimate.net/rayman/. [Accessed 12 October 2020].

[4] A. Matzarakis, T. P. Lin and R.-L. Hwang, "Shading effect on long-term outdoor thermal comfort," Building and Environment, vol. 45, pp. 213-221, 2010.

[5] P. O. Fanger, "Thermal Comfort: Analysis and applications in environmental engineering," McGraw-Hill, 1970.

[6] ANSI/ASHRAE Standard 55-2017, Thermal Environmental Conditions for Human Occupancy.

[7] F. Tartarini, S. Schiavon, T. Cheung and T. Hoyt, "CBE Thermal Comfort Tool: online tool for thermal comfort calculations and visualizations," SoftwareX 12, 2020.

[8] V. Foldvary Licina and e. al, "Development of the ASHRAE Global Thermal Comfort Database II," Building and Environment, vol. 142, pp. 502-512, 2018.
[9] T. Cheung and e. al, "Analysis of the accuracy on PMV – PPD model using the ASHRAE Global Thermal Comfort Database II," *Building and Environment*, vol. 153, pp. 205-217, 2019.

[10] B. Paramita, H. Fukuda, R. P. Khidmat and A. Matzarakis, "Building Configuration of Low-Cost Apartments in Bandung—Its Contribution to the Microclimate and Outdoor Thermal Comfort," *Buildings*, vol. 8, no. 9, 2018.