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Volume 2646 A

# Proceedings of the Symposium on Advance of Sustainable Engineering 2021 (SIMASE 2021)

## Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research

Bandung, Indonesia • 18–19 August 2021

**Editors** • Ade Gafar Abdullah, Astri Rinanti, Deni Miharja, Erfan Rohadi, Farid Triawan, Muhammad Penta Helios and Sudi Dul Aji

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Symposium on Advance of Sustainable Engineering

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*Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research*

**By Ade Gafar Abdullah, Astri Rinanti, Deni Miharja, Erfan Rohadi, Farid Triawan, Muhammad Penta Helios, and Sudi Dul Aji**

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## TITLE INFORMATION

Details

**Summary of this volume:** The *Symposium on Advance of Sustainable Engineering* aimed to provide a venue for engineers, researchers, scholars, and policymakers to explore the challenges of and opportunities from the pandemic on civil engineering, mechanical engineering, manufacturing processes, and engineering materials, and electrical engineering. Civil engineers will play a significant part in the recovery since design and construction services will be needed in the future, and they need to develop new construction methods, materials, and technologies in order to build a sustainable and resilient infrastructure. For manufacturers and engineers, they need to start thinking about the long-term change of their operations and adapt to the new normal that has emerged because of the recent coronavirus pandemic. We welcome all parties to share their research and thoughts in the symposium.

**These proceedings will be of interest to:** industry professionals, students in relevant fields, and any interested parties.

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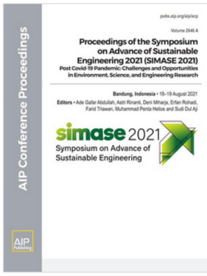


**PROCEEDINGS OF THE SYMPOSIUM ON ADVANCE OF SUSTAINABLE ENGINEERING 2021 (SIMASE 2021): Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research**

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PRELIMINARY

RESEARCH ARTICLE | APRIL 27 2023

# The effect of height and building orientation on thermal comfort sensation using PMV

Putri Alfiah; Popi Puspitasari ✉; Endhi I. Poernomo



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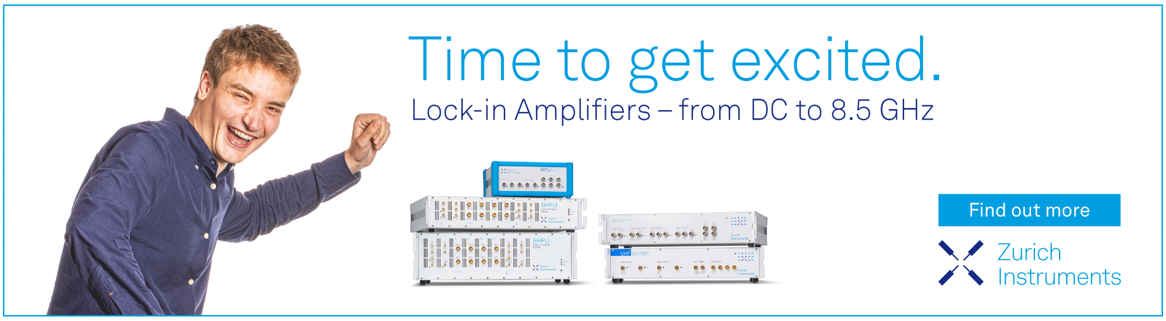

# The Effect of Height and Building Orientation on Thermal Comfort Sensation Using PMV

Putri Alfiah, Popi Puspitasari [a)] and Endhi I. Poernomo

*Architecture Department, Faculty of Civil Engineering and Planning, Universitas Trisakti, Jakarta, Indonesia*

[a)] Corresponding author: popi@trisakti.ac.id



**Abstract.** Unsuitable thermal conditions affect the productivity of indoor activities and cause hyperthermia or hypothermia so that the level of thermal comfort becomes important. The research aimed to compare the effect of building orientation and height of thermal comfort sensation at Building C FTSP Universitas Trisakti. This is also an effort to identify the level of thermal sensation naturally in the room with activities such as reading, writing, standing, and typing, in which the users generally wear trousers, a short-sleeve shirt, socks, shoes, and underwear. The method was descriptive quantitative covering PMV (Predicted Mean Vote) analysis and one-way ANOVA test, using digital anemometers and heat stress meters as data collection tools. The results showed that with tipping window opening of 47cm: 1) the average room temperature at $6^{th}$,$7^{th}$, and $9^{th}$ floors exceeded 6,6ºC-7,3ºC from the standard; the average of wind velocity was below and exceeds 0.2m/s and 5.06m/s; the average room's humidity (48%-85%) was in the standard range; 2) the average thermal sensation was in the warm-hot range, but PMV index values in the west and south were neutral-slightly warm; 3) the orientation and the height of the building floor had no significant effect on thermal comfort sensation.

## INTRODUCTION

Thermal comfort can affect health, welfare, and work productivity [1]. Tarantini et al. [2] found that a comfortable room increases operational work, reduces production defects and worker health costs. Meanwhile, Hughes et al. [3] proved a relationship between low indoor temperature and the health of the elderly. Based on these considerations, research related to thermal comfort is considered essential to improve the comfort quality of the educational building of the Faculty of Civil Engineering and Planning, Universitas Trisakti. The building is intensively used by around 900-1100 students/academic year.

The orientation and height of the building influence the sensation of indoor thermal comfort [4]. Another influencing factor is the use of wall materials, facades, and furniture [5]; the level of outdoor material's albedo, radiated power, and heat reflection [6]; walls' type and material, ventilation system, roof, and bottom structure; geographic position, opening's dimension [7,8]. The openings impact outdoor noise levels and the comfort level of indoor audio [9].

This study aims to compare the sensation of thermal comfort on the sixth, seventh, and ninth floors in Building C, Faculty of Civil Engineering and Planning, Universitas Trisakti, based on differences in building mass orientation and floor height. Albatayneh et al. [10] stated that orientation impacts the overall thermal performance of the building. The sun's north-northeast and west-southwest orientations have the potential to increase the indoor temperature in the case of Binus University located at coordinates E106º38'47.04", S6º13'27.84" [11]. Buildings with an orientation facing southeast have a better level of thermal comfort than other orientations [4].

The density and height of the building affect the potential temperature, the average radiant temperature, and the PMV distribution. So that the vegetation on the ground floor and roof has a relatively high cooling effect [12]. Air

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molecules with warmer temperatures decrease in density (the stretched distance between molecules) so that their density (mass per unit volume) becomes relatively lighter, and the air will float to the top [13]. Kakon et al. [14], using the numerical simulation tool 3d ENVI-met, proved that temperatures at an altitude of 8-9 floors are more comfortable than those at the height of 4-5 floors in the case of Dhaka, Bangladesh. According to Diem [15], the steeper the angle of fall of sunlight, the greater the heat energy received. Likewise, an area with a larger area and higher intensity of sun exposure mean more heat it receives.

In this study, the effect of building orientation and height on the sensation of thermal comfort in rooms on the $6^{th}$,$7^{th}$, and $9^{th}$ floors will be compared through PMV analysis and the One Way ANOVA test. The CBE Thermal Comfort Tool is an analytical tool to help calculate, visualize, and predict thermal comfort sensation according to ASHRAE Standards 55, ISO 7730:2005, and EN 16798–1:2019. The CBE Thermal Comfort Tool combines major thermal comfort models, including Predicted Mean Vote (PMV). The thermal comfort sensation through PMV can be predicted, assuming that humans have an average comfort level in a certain range. Six factors that determine thermal comfort sensation are air temperature, radiation temperature, metabolic rate, clothing insulation, air velocity, and humidity [16]. PMV is an index that indicates the sensation of cold (cold) to hot felt by humans on a scale of +3 to -3. PMV can be used as a tool to estimate the sensation of thermal comfort in a particular room by using the ASHRAE-55 standard thermal comfort component index [17]. The criteria for thermal comfort zones according to ASHRAE-55, 2010, include effective temperature (23°C–27°C), air humidity (30% - 90%), wind speed (0.2 m/s – 0.8 m/s), PMV ($-0.5 < PMV < +0.5$) and PPD ($< 10$). Research is limited to natural lighting by ignoring heat radiation generated by artificial light and air conditioning. Thermal sensation solely relies on the standards set by ASHRAE-55, and the condition of the room is empty.

## METHODS

The research approach was descriptive statistics using PMV analysis displayed on psychometric charts on the CBE Thermal Comfort Tool, and a one-way ANOVA test was used to compare the result of PMV analysis. The research population was the point in all rooms on the $6^{th}$, $7^{th}$, and $9^{th}$ floors of Building C, Faculty of Civil Engineering and Planning, Universitas Trisakti. While the sample was the measurement points representing the area near the inlet, center area of the room, and area near the outlet. Research variables included:

- independent variables (orientation and height of the building floor);
- dependent variables (value of Predicted Mean Vote analysis); and
- moderate variables (temperature, wind speed, humidity, metabolic rate, and clothing insulation).

The research instruments were four 3 in 1 digital anemometers and one heat stress meter. Measurements were set at 12 points with three different points in each room positioned according to the four cardinal directions – north, west, east, and south (see Fig. 1). Outdoor points were installed at the height of ± 60cm above the floor level and ± 1 m for indoor points. The measurement time was at 11:30 – 14:30, and when measuring, the windows were opened as wide as ± 47cm and did not use artificial ventilation but natural ventilation.

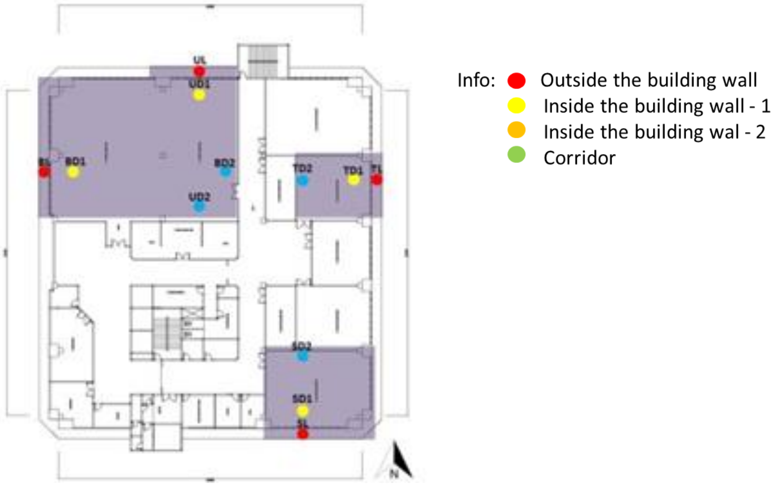


**FIGURE 1.** Location of measurement points on the 6th floor (also applies to 7th and 9th floors) (Source: Alfiah, 2021)

# RESULTS

## PMV Analysis Results

The measurement results on the 6th floor showed that the highest (35.2ºC) and lowest (29.6ºC) temperatures were rooms oriented to the west. The room with east orientation had the highest humidity (73.5%), while the lowest (56.7%) was in the west and east-oriented rooms. The highest wind velocity was in the rooms oriented to the east of 4.73 m/s.

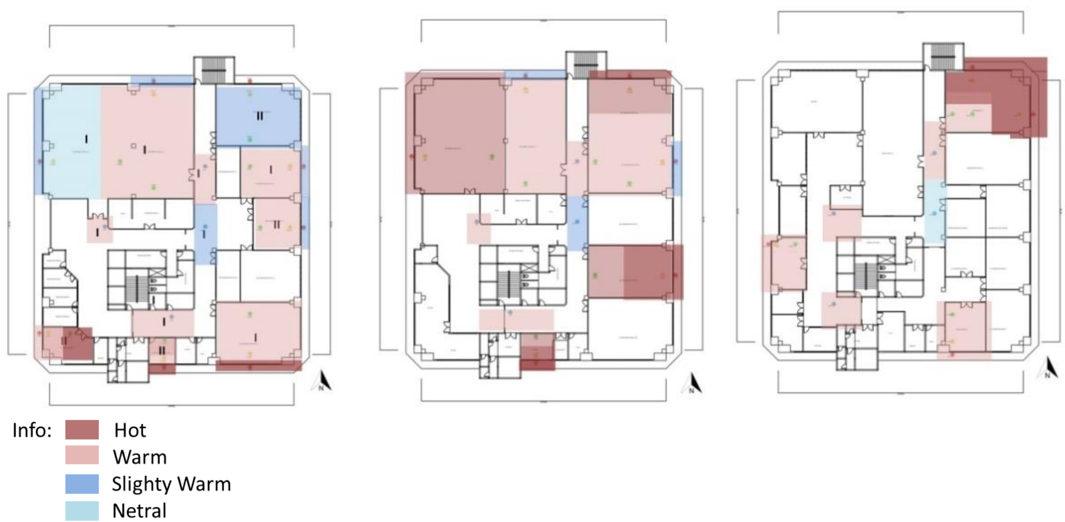


**FIGURE 2.** Thermal sensation zoning on 6th, 7th, and 9th floors of Building C, Faculty of Civil Engineering and Planning, Universitas Trisakti (Source: Alfiah,2021)

On the 7th floor, the room with the highest temperature (38.5ºC) had the north orientation, while the lowest temperature (29.1ºC) was the room oriented towards the east. The highest (76.5%) and the lowest (53.5%) air humidity occurred in a room oriented to the north, while the highest wind velocity (5.06 m/s) was in the room oriented to the east. On the 9th floor, the highest room temperature (36.7ºC) was in the east and west, while the lowest (28.6ºC) was in the west. The highest room air humidity (85%) was in the west orientation, the lowest (48%) was in the east and north, and the highest inlet wind velocity (4.93m/s) was in the west and north rooms.

Based on the PMV value analysis, the room on the 6th floor with a south orientation has a PMV value of 3.04 (hot) and a western orientation of 0.39 (neutral). The highest PMV value on the 7th floor is in a room with a north orientation of 4.23 (hot) and the lowest -0.01 (neutral) in an east orientation. While on the 9th floor, the highest PMV value is in a room with an east orientation (4.03, hot), and the lowest value is a room with a west orientation (-0.20, neutral). Of the three floors, the higher the floor height, the average thermal sensation felt is warm to hot, and the lower the floor height, the thermal sensation felt is neutral to slightly warm (see Fig. 2 and Fig. 3).

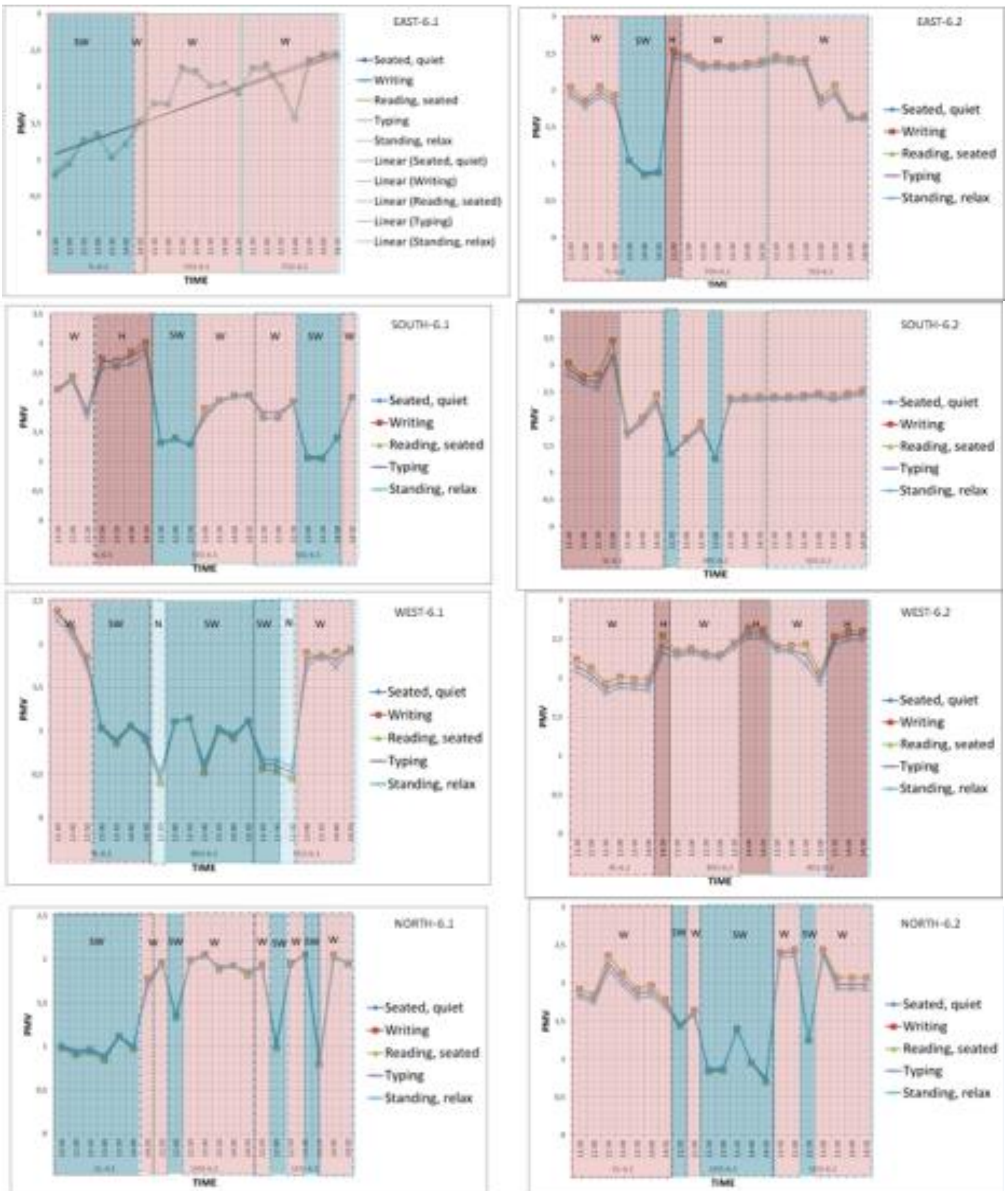


**FIGURE 3.** Thermal sensation zoning on 6th floor (east, south, west, north) – as an example of research results (Source: Alfiah, 2021)

## One Way ANOVA Test Results

According to the validity test criteria, if the Sig value is less than 0.05, there is a significant difference. In the ANOVA test results, the Sig value for the height of the building floor obtained was 0.108 > 0.05 and for building orientation was 0.827 > 0.05, indicating no significant difference in PMV values between the rooms on the three floors studied. So it can be concluded that the floor height and building orientation had no significant effect on the PMV value (see table 1 and 2).

**TABLE 1.** One Way ANOVA test result based on differences in Building Floor Height

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | ,291 | 2 | ,146 | 2,695 | ,108 |
| Within Groups | ,648 | 12 | ,054 | | |
| Total | ,939 | 14 | | | |

Source: Alfiah, 2021

**TABLE 2.** One Way ANOVA test based on differences in Building Orientation

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | ,081 | 3 | ,027 | ,296 | ,827 |
| Within Groups | ,726 | 8 | ,091 | | |
| Total | ,806 | 11 | | | |

Source: Alfiah, 2021

## CONCLUSION

The average room temperature on the sixth, seventh and ninth floors (30.3°C-33.6°C) exceeds 6.6°C -7.3°C of the thermal comfort standard (23°C -27°C), the lower threshold of the average wind speed is 0.08 m/s below the standard (0.2 m/s), but the upper threshold exceeds the standard (0.8 m/s) which is 5.06 m/s, humidity the room average of 48%-85% is in the standard range of 30%-90% humidity. The higher the building floor, the predicted average thermal sensation is in the warm-hot range, but the PMV index shows a dominant neutral-slightly warm in the west and south. Through the one-way ANOVA test, the orientation and height of the building floor in the case studied did not significantly affect the comfortable sensation calculated through PMV analysis. Thus, indoor thermal comfort cannot rely entirely on natural thermal conditions, so additional tools are needed to increase the movement of wind speed in the room.

## ACKNOWLEDGMENTS

We thank Universitas Trisakti, especially The Faculty Of Civil Engineering And Planning for supporting us. This research could not have been accomplished without their support.

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Putri Alfiah, Popi Puspitasari [a)] and Endhi I. Poernomo

*Architecture Department, Faculty of Civil Engineering and Planning, Universitas Trisakti, Jakarta, Indonesia*

[a)] Corresponding author: popi@trisakti.ac.id



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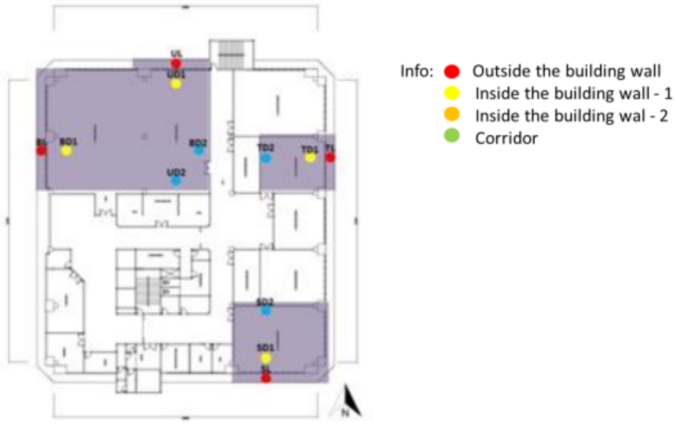


**FIGURE 1.** Location of measurement points on the 6th floor (also applies to 7th and 9th floors) (Source: Alfiah, 2021)

# RESULTS

## PMV Analysis Results

The measurement results on the 6th floor showed that the highest (35.2°C) and lowest (29.6°C) temperatures were rooms oriented to the west. The room with east orientation had the highest humidity (73.5%), while the lowest (56.7%) was in the west and east-oriented rooms. The highest wind velocity was in the rooms oriented to the east of 4.73 m/s.


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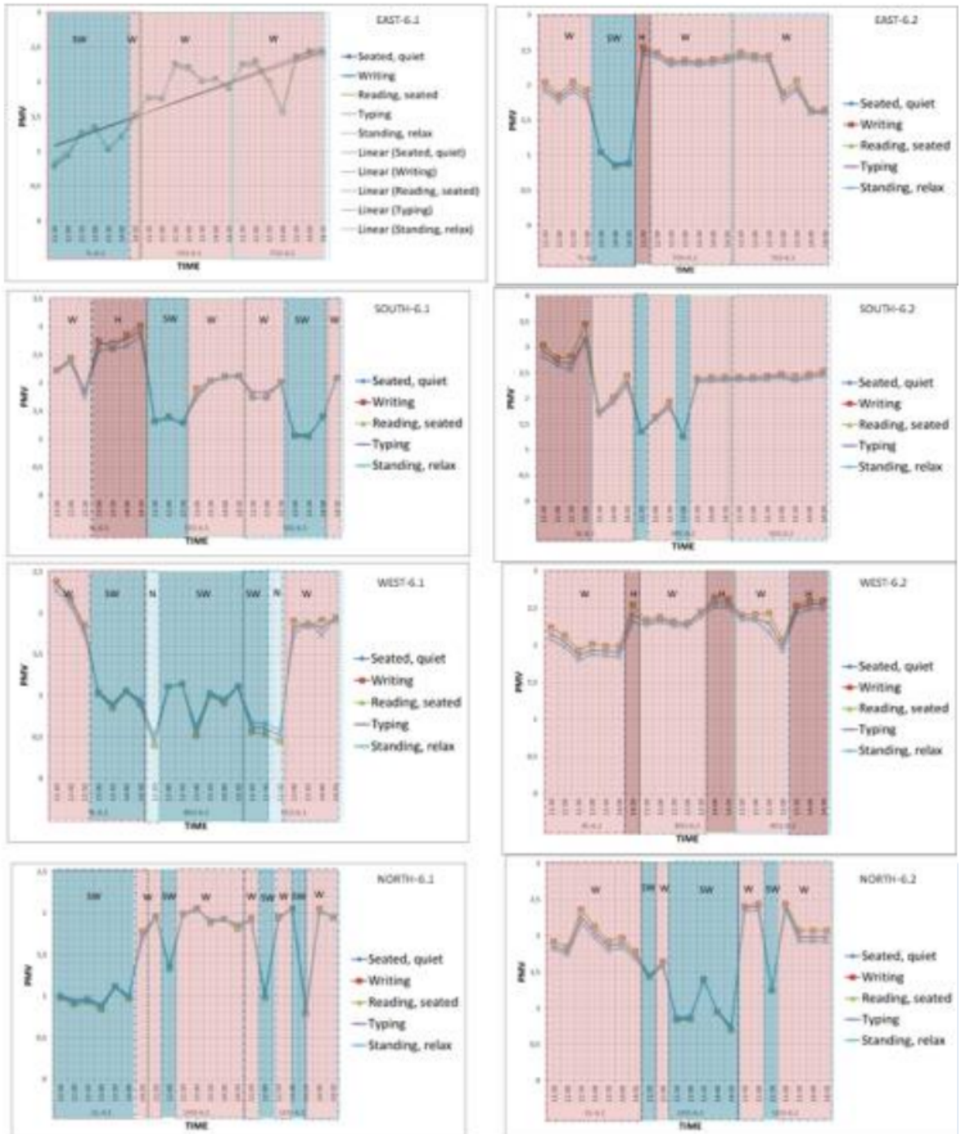


**FIGURE 3.** Thermal sensation zoning on 6th floor (east, south, west, north) – as an example of research results (Source: Alfiah, 2021)

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| | Sum of Squares | df | Mean Square | F | Sig. |
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| Between Groups | ,291 | 2 | ,146 | 2,695 | ,108 |
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RESEARCH ARTICLE | APRIL 27 2023

# The effect of height and building orientation on thermal comfort sensation using PMV

Putri Alfiah; Popi Puspitasari; Endhi I. Poernomo



+ Author & Article Information

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Unsuitable thermal conditions affect the productivity of indoor activities and cause hyperthermia or hypothermia so that the level of thermal comfort becomes important. The research aimed to compare the effect of building orientation and height of thermal comfort sensation at Building C FTSP Universitas Trisakti. This is also an effort to identify the level of thermal sensation naturally in the room with activities such as reading, writing, standing, and typing, in which the users generally wear trousers, a short-sleeve shirt, socks, shoes, and underwear. The method was descriptive quantitative covering PMV (Predicted Mean Vote) analysis and one-way ANOVA test, using digital anemometers and heat stress meters as data collection tools. The results showed that with tipping window opening of 47cm: 1) the average room temperature at 6th,7th, and 9th floors exceeded 6,6°C-7,3°C from the standard; the average of wind velocity was below and exceeds 0.2m/s and 5.06m/s; the average room's humidity (48%-85%) was in the standard range; 2) the average thermal sensation was in the warm-hot range, but PMV index values in the west and south were neutral-slightly warm; 3) the orientation and the height of the building floor had no significant effect on thermal comfort sensation.

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RESEARCH ARTICLE | APRIL 27 2023

# Preface: Proceedings of the Symposium on Advance of Sustainable Engineering 2021 (SIMASE 2021): Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research



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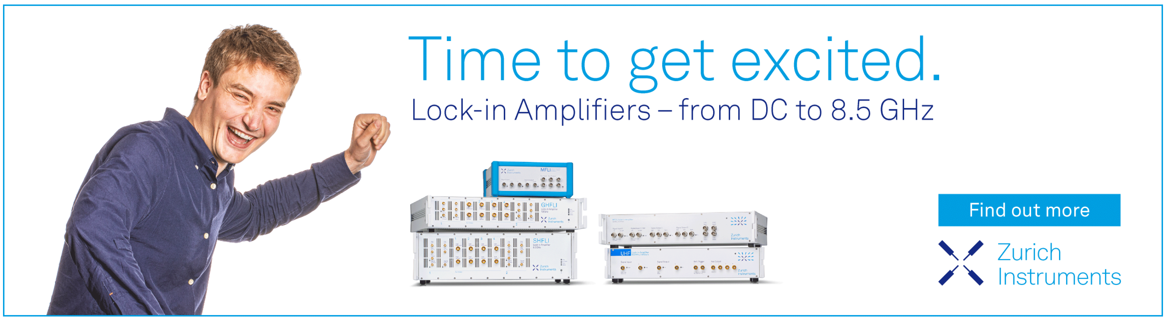

# PREFACE: Proceedings of the Symposium on Advance of Sustainable Engineering 2021 (SIMASE 2021)

## *Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research*

It is with great pleasure to welcome you to Symposium on Advances of Sustainable Engineering (SIMASE) 2021 hosted by Rumah Publikasi Indonesian on August 18-19, 2021. The event aims to a venue for engineers, researchers, scholars, and policy makers to explore the challenges and opportunities from the pandemic on civil engineering, mechanical engineering, manufacturing process and engineering materials, and electrical engineering. For civil engineers, they will play a significant part in the recovery since design and consutrcion services will be needed in the future, and they need to develop new construction methods, materials, and technologies in order to build a sustainable and resilient infrastructure. For manufacturers and engineers, they need to start thinking about the long-term change of their operations and adapt to the "new normal" that has emerged because of the epidemic. We welcome all parties to share their research and thoughts in the symposium.

Participants of the symposium were invited to submit their papers and disseminate them through virtual oral presentation covering such scope as civil engineering, mechanical engineering, manufacturing process and engineering materials, and electrical engineering. To enrich the discussion under the theme of "Post-COVID-19 pandemic: challenges and opportunities in environmental, science, and engineering research', we invited speakers with reputable expertise, namely Dr. Eng. Farid Triawan from Sampoerna University, Indonesia; Prof. Josaphat Tetuko Sri Sumantyo, Ph.D. from Chiba University, Japan; Prof. Andrivo Rusydi, Ph.D. from National University of Singapore (NUS), Singapore; Dr. Eng. Gagus Ketut Sunnardianto from Indosian Institue of Science (LIPI), Indonesia; and Dr. Astri Rinanti Nugroho from Universitas Trisakti, Indonesia. In addition to presenting their research results, the participants of the symposium were also encouraged to submit their papers to be proposed for publication to American Institute of Physics (AIP), one of the world's top publishers as conference proceedings. There were 309 manuscripts submitted to the committee comprising 256 papers of Biology, Chemistry, Computer Science and Technology, Engineering, and General Physics.

Finally, on behalf of the editors of SIMASE 2021, I would like to extend my most sincere gratitude to the organizing committee, co-hosting institutions, and most importantly, participants, speakers, presenters, and authors of the symposium. I do hope the proceedings bring significant contribution, particularly to the field of advances of sustainable engineering. I look forward to seeing you all at the upcoming symposium.

The Editors,
Ade Gafar Abdullah
Astri Rinanti
Deni Miharja
Erfan Rohadi
Farid Triawan
Muhammad Penta Helios
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# Committees: Proceedings of the Symposium on Advance of Sustainable Engineering 2021 (SIMASE 2021): Post Covid-19 Pandemic: Challenges and Opportunities in Environment, Science, and Engineering Research



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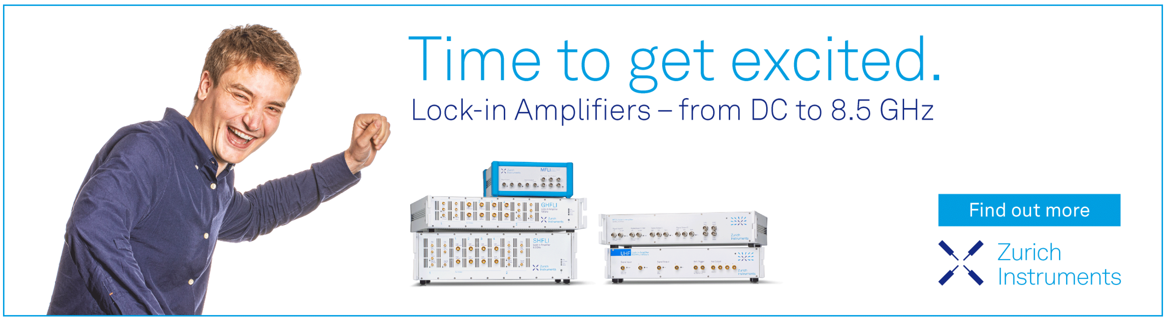

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