Thermal Comfort in East Campus Center of ITB Bandung

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Abstract. The campus center is the building regarded as the center of student activities. It's the typical building commonly found on campuses. The building is specifically intended for the students to entertain and socialize themselves. The building can also function as the center for small-scale conference conferences; the meeting is leased to student communities and local organizations. By various activities taking place in the building, it's demanded to meet the need for the users' thermal comfort to realize all of their programs following their objectives respectively. The study on ITB Campus Center Building aims to encourage students to be familiar with the influence of the building orientation, dimensions, shape, material, configuration, and the opening type that affect the space's air circulation. This research used a quantitative descriptive method approach by measuring the temperature and humidity through the gauge for temperature and humidity and an anemometer for wind speed. It identifies the study object's thermal comfort based on the PMV Index in the CBE Thermal Comfort Tools. And from the results of our research, it can be concluded that the building has fulfilled most aspects of thermal comfort.

1. Introduction

According to Szokolay (1973), thermal comfort is a psychological condition that expresses his satisfaction with the thermal environment. Some factors affect thermal comfort, including air temperature, average radiation temperature, humidity, and wind movement [1]. Increasingly sophisticated technological developments affect the design of the buildings that will be and have already been designed. Many buildings prioritize aesthetic values but do not rule out optimal aspects, such as thermal comfort in buildings. Back again to the building's main function, apart from a place that will support all of our activities, it will provide a sense of security and comfort. Each building is expected to provide thermal, visual, and auditory comfort.

Indonesia's geographical position is located between Australia and Asia and between the Indian Ocean and the Pacific Ocean. Meanwhile, astronomically, Indonesia is located at six o NL (North Latitude) - 11 o SL (South Latitude) and 95 o EL (East Longitude) - 141 o EL (East Longitude). This location will impact each building, including thermal comfort at the building [2].

Regarding the ITB Campus Center building, which has become the object of this case study, the ITB Campus Center building itself is a building that functions as a center for student activities [3]. They can also carry out various activities, such as scientific discussions, sports, cultural arts, or preaching. They can also develop interests and talents in some student activity units. When viewed from its geographical location, Indonesia has tropical climatic conditions. This, of course, has very high humidity and air temperature. High solar radiation will interfere with the user's activities, while each unit is required to meet the thermal comfort that the body needs so that users can do activities properly.

This study has the objective of knowing and understanding how the building orientation influences; dimensions and shape of the building; building materials; building configuration; placement and orientation, location and dimensions of the opening; as well as the direction and type of openings that affect the movement of air in the space [4]. Previous research has conducted studies related to the
Campus Center by linking various factors, including building orientation; dimensions and shape of the building; building materials; building configuration; placement and orientation, location and dimensions of the opening; and guide and aperture type for thermal comfort. In this study, it was found that the influence of building design and opening design in supporting thermal comfort [5].

The study at the ITB Campus Center Bandung building has the objective of knowing and understanding how the building orientation, dimensions and shape, materials, configuration, and openings can affect the thermal comfort conditions. This study also tries to evaluate the quality of thermal comfort in case studies. The benefit of this research is to provide insight and input into the design of educational buildings, especially student activity centers.

2. Methodology

The research method used in this study uses descriptive quantitative research methods. We take temperature measurements and measure air temperature using a temperature measuring instrument and a measurement, namely Humidity / Temp. Meter, and wind speed measuring device, namely Anemometer. Data was taken on September 28, 2019, from 7.00 am to 5.00 pm.

This research was conducted in several stages. First, conduct a literature review related to thermal comfort about the ITB Campus Center Bandung building for student activities through book sources and previous studies. Second, observe the object of study in the field and take direct measurements of primary data such as temperature, humidity, and wind speed. Third, discussing the building orientation, dimensions, shape, material, configuration, and the opening type based on observations of the object of study and the literature review. The fourth stage identifies the study object's thermal comfort based on the PMV Index in the CBE Thermal Comfort Tools. And the last stage is the conclusion.

3. Case Study

The case study studied in this research is the ITB Campus Center in Bandung. ITB is located in the central part of Bandung, on Jl. Ganesha and close to Jl. Dago. ITB is one of the major campuses in the city of Bandung and has a long history. ITB continues to grow until now, both physically and non-physically. ITB Campus Center is one of the buildings built-in 1920. The function of this building is to accommodate student activities such as recreation and socializing. This building's location is in the middle of the ITB campus due to its function crisis. In this study, researchers conducted observations and measurements at several location points representing thermal conditions in buildings and the environment. There are eight measurement points taken. Four points are performed outside the building and four more points inside the building. Measurement points and an overview of building and environmental conditions can be seen in the Figure below.

![Figure 1. Case study and measurement position](Source: Authors private data)
4. Result and Discussion
In the first part, this chapter will explain the characteristics of the building orientation, dimensions, shape, material, configuration, and the opening type based on observations. These characteristics are studied based on existing theories to find their relation to the thermal comfort of buildings.

4.1. Building Characteristic
4.1.1. Building Orientation. The orientation of buildings to the sun affects the air temperature increase in the room [6]. Likewise, solar radiation can cause the space in tropical buildings to increase temperature, which causes the room to feel hot [7]. Based on SNI 03-6389-2000 concerning Conservation of Building Envelope Energy in Buildings, buildings facing west receive the highest radiation compared to radiation from other directions, 243 W / m².

In the case study in the ITB Campus Center building, the building's orientation is to the north and south. Many openings are placed in the north-south of the building, so less radiation enters the building. It causes an increase in temperature in the room in the building. The western and eastern parts of the building use brick walls and have a few openings to only a little solar radiation enter the building. So, based on this, the orientation of this building is good.

![Figure 2. The orientation of the solar radiation](image)

Figure 2. The orientation of the solar radiation
Source: Authors private data

4.1.2. Configuration and The Shape Of The Building

![Figure 3. The effect of building shape on wind movement](image)

Figure 3. The effect of building shape on wind movement
Source: Authors private data

Based on the research results, the building's configuration & shape affect thermal comfort because it can control the movement of air or wind outside the building by utilizing differences in air pressure [8].

The building's height and width will affect the wind shadow area (leeward) behind the building. The area of the wind shadow can reach three times the width of the ITB Campus Center building. The wider the wind shadow area, the slower the building's wind speed will reduce its thermal comfort [9].
A hallway in the ITB Campus Center area will catch, channel, and advance or even spread the airflow. However, if the airflow enters the hallway from the opposite direction than expected, it can spread and disrupt, causing unexpected effects [8].

![Figure 4. The effect of building configuration on wind movement](source: Authors private data)

The building's linear configuration in the ITB Campus Center area blocks airflow in the next building, forming a quiet area between the two buildings.

### 4.1.3. Building Materials

| No. | Type of material | Color | Photo |
|-----|------------------|-------|-------|
| 1   | Brick with stucco on both sides with a white paint finish. | White | ![Figure 5. Side of the building](source: Authors private data) |
| 2   | Glass as a substitute for walls with a height of 2 floors | - | ![Figure 6. Use of glasses as a substitute for walls](source: Authors private data) |

The building material's selection can be adjusted to withstand heat to obtain an adequate thermal comfort level. The heat flow rate in the building that penetrates the material will be inhibited [10]. The first layer on the wall will absorb heat when the heat energy falls on the wall's surface and passes it on to the next layer. It causes a delay effect for some time, which causes temperature changes in the new environment or is called "time lag." So that if the building material has a massive and heavy mass, it will also have a large time lag and cause more stable thermal conditions [10].

The wall material and colors at the ITB Campus Center use bricks with both sides painted white with the transmittance rate not too large so that the heat transmitted into the room is not too large. Brick has a time lag of 2.5 hours, much greater than wood material, which only has 10 minutes. This results in the brick can absorb heat more than wood material. On the outside, it is dominated by the glass as a cover. Glass material has a U-value of 6 W / m²K, which means that the material has a sufficiently large heat conductivity, thus making the temperature in the room hot. However, the many air vents around the building make the air inside the building cool.

But the problem is, what if the outside air has a hot temperature? It will have an impact on winds that are brought from the south and north outside the building. The wind can then bring hot air from outside the building into the room, increasing the room temperature.
Choosing the right material can help correct temperatures that are not compatible with thermal comfort. On the other hand, if the material is wrong, it will result in low thermal comfort. One of the examples is the ITB Campus Center building. Too much glass material in buildings can also trigger an increase in temperature because glass can cause solar radiation heat to enter the building but is trapped inside [12].

The pavement area that is too close to the building causes heat during the day. It heats the asphalt and gravel around the building to increase its temperature [13]. It can be seen in the table that the temperature jumps sharply when the clock shows 1:00 pm - 2:00 pm. It is due to the use of heat-absorbing pebble tile and the lack of trees as shade around them.

| Time       | T (°C) |
|------------|--------|
| 7:00 am    | 24.8   |
| 8:00 am    | 27     |
| 9:00 am    | 27     |
| 10:00 am   | 29.5   |
| 11:00 am   | 29.3   |
| 12:00 pm   | 29.2   |
| 1:00 pm    | 32.6   |
| 2:00 pm    | 35.5   |
| 3:00 pm    | 30.6   |
| 4:00 pm    | 29.3   |

Source: Authors private data

4.2. Internal Factor of Thermal Comfort

Several internal factors affect the comfort of a building. Among them are the opening factor in buildings and building materials. If these two aspects are not considered, it can be ensured that the building's thermal comfort will be below.

4.2.1. The Opening Design of The Building. The building has two different types of openings. The first is a large opening in the middle of the building. These openings are cross ventilation, which is an opening that functions to flow air from outside, into and through various rooms until finally out. It is useful for reducing the humidity in the room and turning it into fresh airflow. Cross-ventilation has various functions, including ventilation, airflow, and lighting optimizer [11].

The second opening is small. These openings are windows arranged parallel to the length of the building. Windows flow air from outside into every room.
4.3. External Factor of Thermal Comfort

Apart from internal factors, there are also external factors that also affect thermal comfort. A vegetation and air movement, for example, are contributing factors to the occurrence of thermal comfort in a building.

4.3.1. The Effect of Vegetation. In this building area, pavement areas such as asphalt and gravel are closer to the building than vegetation. So that asphalt and gravel have more effect on the thermal comfort of buildings than on the vegetation.

In designing a building, we should pay more attention to green areas and pavements, which areas should be located near the building because this can affect the building’s thermal comfort.

4.4. Thermal Comfort Measurement in East Campus Center Of ITB Bandung

Measurements are made by measuring temperature, humidity, and wind speed using an anemometer. Measurements are carried out at 7:00 am - 4:00 pm on September 28, 2019. Measurements were also carried out into two categories, outside the building and inside the building, carried out on the four sides of the building, north, east, south, and west. view image.
4.4.1. Temperature and Humidity. Based on the measurement results, the most extreme temperature changes occurred on the east side. It is due to several factors such as the state of vegetation and materials on the north side, followed by the northern position. The striking temperature difference can be seen through the temperature comparison table below.

Table 3. Average temperature comparison table

| Position | Inside   | Outside  |
|----------|----------|----------|
| West     | 28.46 °C | 29.48 °C |
| North    | 28.17 °C | 29.91 °C |
| East     | 28.05 °C | 29.31 °C |
| South    | 28.08 °C | 28.43 °C |

Source: Authors private data

Measurement of temperature outer northern position is the most significant example of a large amount of asphalt material around the building. The amount of glass material that reflects light causes high heat. Asphalt material has an extreme temperature difference between day and night. It will reduce thermal comfort [14].

Table 4. Table of Temperature, wind speed, and humidity at the northern side of the building

| Time      | T (°C) | RH (%) | V (m/s) |
|-----------|--------|--------|---------|
| 7:15 am   | 24.3   | 63     | 0.055   |
| 8:15 am   | 26.2   | 57     | 0.24    |
| 9:15 am   | 29.3   | 48     | 0.569   |
| 10:15 am  | 30     | 46     | 0.215   |
| 11:15 am  | 31.3   | 45     | 0.309   |
| 12:15 pm  | 30.5   | 45     | 0.127   |
| 13:15 pm  | 32.7   | 30     | 0.565   |
| 14:15 pm  | 34     | 28     | 0.748   |
| 15:15 pm  | 31.1   | 41     | 0.429   |
| 16:15 pm  | 29.7   | 46     | 0.119   |

Source: Authors private data

Figure 11. Temperature, wind speed, and humidity at the northern side of the building

Source: Authors private data

Based on the table, it can be concluded that temperature is inversely proportional to humidity, where when the temperature increases, the humidity decreases, and vice versa [15]. And both are very affected by the existing wind speed.
4.4.2. Wind Speed. Based on the measurement results, the highest wind speed is on the southern side. It is due to the movement of the east monsoon winds from Australia to Asia during the measurement. The East Monsoon winds are the winds that blow from April to October. It is due to the high pressure on the Australian continent. The wind is dry because it brings dry air [16]. They are followed by the east side, where there is a tunnel that causes an increase in wind speed. While on the inside, the opening factor is the factor that most influences the wind speed that occurs. The following is a wind speed comparison table.

| Position | Inside (m/s) | Outside (m/s) |
|----------|-------------|---------------|
| West     | 0.799       | 0.48          |
| North    | 0.115       | 0.748         |
| East     | 0.299       | 0.746         |
| South    | 0.591       | 0.817         |

Source: Authors private data

The same thing is shown by measurements using the windrose application. By using the Windrose application, we can see which sides are often exposed by the wind. And based on the application, it shows that the southern and eastern sides are the most dominant sides exposed by strong winds.

4.5. Measurement by using CBE Thermal Comfort

Besides measuring the temperature manually using an anemometer or thermometer, we can also determine the thermal comfort by using the software or application. One of them is the CBE Thermal Comfort Tool software developed by the Berkeley University of California. Right there, we can adjust the temperature, humidity, wind speed, metabolic rate, and clothing level so that the operative temperature can be determined. Or it can be called the most suitable and comfortable temperature standard. The method used by this tool is Predicted Mean Vote (PMV). The reference standard for thermal comfort is ASHRAE standard 55-2017. Activities that are entered as input are 1.2 meters, which describe the standing condition. The clothing level parameter used is 0.74 clo, namely sweatpants and long-sleeve sweatshirts.

First, the space in the building is checked for its thermal comfort qualities. Checking the quality of thermal comfort is only carried out at extreme temperatures at 2:00 pm. Based on the measurement data processed on the CBE Thermal Comfort Tool, it can be interpreted that the four measured points describe an uncomfortable thermal condition at 2:00 pm hours (see Figure 11). Only the H position of the four positions is close to the thermal comfort value, which is the slightly warm one. As previously mentioned,
this occurs due to many factors, including the use of inappropriate materials so that they absorb and retain the heat longer, such as glass, asphalt, pebble, and the use of dark colors.

\[ E \]

\[ F \]

\[ G \]

\[ H \]

**Figure 13.** Indoor thermal comfort using CBE Thermal Comfort Tool, point E, F, G, H

Source: data processing and analysis with comfort.cbe.berkeley.edu

Checking the quality of thermal comfort is also carried out in the outdoor area of the building. Based on the measurement data processed on the CBE Thermal Comfort Tool, it can be interpreted that the four measured points describe a thermal condition that is uncomfortable (warm) at 2:00 pm. Only the D position of the four positions is close to the thermal comfort value, which is the slightly warm one. This can happen because of the amount of vegetation in the fourth position, providing oxygen supply and shade to the building. Besides, the wind that comes from the south is also a supporting factor for increasing thermal comfort there.
Based on thermal comfort evaluation, at extreme hours (2:00 pm), most locations fall into the warm category. The consideration of building orientation, dimensions and shape, materials, configuration, and opening previously discussed can be used as design input for the Campus Center building. Thermal comfort is affected by various internal and external aspects such as opening, humidity, and wind speed [17].

5. Conclusion
The thermal comfort study analysis at the ITB Campus Center building is reviewed based on the building design, air opening design, internal factors, and external factors that affect thermal comfort. From the results of this analysis, the following conclusions can be drawn:

1. The large area of the building envelope is in a north-south orientation. A hallway in the ITB Campus Center area will catch, channel, and advance or even spread the airflow. The building uses bricks with both sides painted white. The building envelope is dominated by glass material (north-south), which can receive heat through radiation and conduction. Asphalt and gravel tile materials that have the potential to absorb heat are widely used around buildings. The placement of vegetation to the south of the building, which is a potential wind direction source, can increase air humidity and buffer the wind.

2. Based on the measurement results, the most extreme temperature changes occurred on the east side. On the other hand, the highest wind speed was on the south side of the building.

3. From the PMV analysis, it is known that most of the ITB Campus Center building (indoor-outdoor) areas at extreme hours (14.00 WIB) in general have not reached the thermal comfort aspect (warm category). This condition can be caused by the use of asphalt material and gravel tiles, which can absorb heat widely used around buildings. On the other hand, the building's south position is the best thermal comfort position (outdoor and indoor) among others (slightly warm category). This condition can be caused by the hallway, vegetation, and building openings in the southern area.

4. The analysis results that we have conducted haven't been perfect yet and still require deeper study at another time. An in-depth study of each factor is demanded to get more accurate results.

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