Factor of building orientation direction as determinant the thermal comfort quality

James Rilatupa

1Architecure Departemnt, Faculty of Engineering, Tarumanagara University, Jl. Letjen S. Parman No.1, Jakarta 11440, Indonesia

1jedrilatupa@gmail.com

Abstract. Generally determines the comfort quality of rooms in the building is due to the air temperature caused by solar radiation, humidity and air movement inside the building. A comfortable room influenced by the volume of space, wide opening in the wall, use of materials, patterns of shadows and vegetation around the building. But the specific factors that can impact directly on the quality level of comfort rooms in the building that is the building position with a different orientation direction. Standard guidelines thermal comfort for the humid tropics to be achieved is at the limit of 24°C < T <26°C. Thermal comfort research was conducted in a pilot house in the Faculty of Engineering, Christian University of Indonesia (FT-UKI), Cawang, East Jakarta. The thermal comfort research lasts for 2 (two) months. Indoor air temperature in the pilot house of FT-UKI does not meet the requirements of thermal comfort standard for each building orientation direction during the research. But on average, building orientation direction were relatively convenience in this research is northwest - southeast, it also minimizes design of engineering and construction to the surrounding environment.

1. Introduction

Convenience of a building can be categorized in the comfort temperature/thermal, visual comfort and acoustic/aural comfort. But its own comfort is more subjective, level of individual comfort differs depending on the physical conditions (sex, age, body shape, skin colour, health, food and beverage as well as the ability to adapt) and living conditions/environment [11]. Humans are given the ability to adapt to the state of nature/natural environment, but still have the limitations that still need tools like form of clothing, and the built environment/building. The form of human adaptation in one place to another place is different depending on the environmental conditions [4]. Despite that, there is a standard human comfort, because the physical condition of man in various parts of the world is not much different. To determine the standard of human comfort in terms of thermal, visual and acoustic first need to understand the each characteristic of these factors [12].

According to UN Habitat [20], to make a planning and conduct of good building, conditions of local climatic need to be noticed namely:
a) The factors that might affect the comfort, mental and physical abilities of the occupants (solar radiation, temperature and its changing, rainfall, humidity, air movement and air pollution).
b) The factors that might affect the safety of buildings (earthquake, storm, heavy rains and floods, tidal wave and biohazard).

c) Any factor that may cause damage to buildings and caused deterioration of building materials early (factor that it was mentioned on grain b, a strong intensity of the sun, a high of air humidity and condensation, dust storms and sand, as well as the content of salt in air).

Furthermore, there are four basic environmental variables that affect human responses to thermal comfort [6, 12], namely:

a) Air temperature. The temperature of the air that a person is in contact with, measured by the dry bulb temperature (DBT). Air temperature also can be defined as the temperature of the air surrounding the human body which is representative of that aspect of surroundings, which determines heat flow between the human body and the air. Naturally the temperature of air will vary. The temperature of the air at a great distance of human body.

b) The radiant temperature is heat exchange by radiations between all bodies. The overall radiation field, in a room for example, can be defined in terms of heat transfer or, more conveniently, in term of radiant temperature. This is generally expressed as mean radiant temperature (MRT).

c) The humidity of environment is a basic parameter. It can be expressed in a number of forms; however ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature, expressed as a percentage. The higher the relative humidity, the more difficult it is to lose heat through the evaporation of sweat.

d) The air movement (in combination with the air temperature) will affect the rate at which warm air or vapour is taken away from the body, thus affecting the body temperature. Air movement measured in m/s. The faster the air is moving, the greater the exchange of heat between the person and the air (for example, draughts generally make us feel colder).

In connection with the building, the comfort is defined as a specific condition that can provide a pleasant sensation for the user of building [1, 5]. Most of the time, human beings become the victim of their own built environment. Man is said to be thermally comfortable when he can’t say whether he wants change in temperature is hotter or colder in a room [16]. According to Karyono [10], comfort is influenced by some objective factors, namely air temperature, wind movement, air humidity, radiation. Thermal comfort is also influenced by subjective factors, such as metabolism, clothing, food and drink, body shape, and age and gender. Meanwhile, if we look into a room in which there is the venue for an activity of humans it is necessary to consider the convenience of the users of that room, where people need the temperature, relative humidity and air right in order to feel comfortable [18]. The success of the space planning is determined by the user convenience, whether the room was functioning properly in accordance with the desired, or into the unused space because no comfortable room to wearing them [15].

The relationship between human and environmental is complex and active, bringing in time, climate, building form, social conditioning, economic and other factors, as well as an immediate physical environment. This complexity implies that the indoor environment needs to take this variability in account. This means an indoor environment that changes with the season and the climate that allows buildings, suggests how quickly they should do so and reflects the willingness of occupants to vary their environment by returning some measure of control to them. In many researches of user satisfaction in building found that having the ‘right temperature’ was one of the things human considered most important about the building [3, 6]. Failure of human beings to respond to the environment through thermo-regulatory mechanism causes thermal discomfort. The thermal discomfort experience by occupants of a built
environment during hot season causes lower emotional health manifested as psychological distress, depression and anxiety as well as lower physical health manifested as heart disease, insomnia, headache, fatigue, boredom and poor arousal [8].

According to Brown and Gillespie [2], an energy budget of a person considers all streams of energy to the person – metabolic energy (generated within the body) and radiation from the sun and from all objects on earth) and all losses of energy from the person – evaporation (due to perspiration), convection (due to wind) and radiation. These main streams of energy are affected mainly by the climatic elements: air temperature, humidity, wind, and solar radiation. Meanwhile, the orientation of a building is a contributing factor on how much energy it would use to provide thermal comfort for its occupants. The amount of sunshine that enters an interior space is affected by the building orientation [10]. Therefore, the level of productivity and human health is strongly influenced by local climatic conditions [17].

Thermal comfort has been studied by many researchers in Indonesia; like Henry Feriadi [7] and Sugini [19] to a number of respondents in the residential area of the Yogyakarta, Mom dan Wiesebron [14] in Bandung, Karyono in Jakarta [9] and others researchers. It means building orientation researches are important for necessary to establish a building. The aim of this research is to compare the effect of building orientation with air temperature, relative humidity, and air movement the indoor of FT-UKI pilot house.

2. Methodology
This research was conducted in a pilot house (stage house) that has 3 wheels, so it can be rotated in the direction of orientation. The pilot house size is 360 x 360 cm$^2$ which is located on the Faculty of Engineering, Christian University of Indonesia (FT-UKI), Cawang, East Jakarta (Figure 1). This research lasted for 2 (two) months. A material used in this research is three-wheeled and rotatable pilot house. While the tools used are examination accreditation forms, stationery, temperature gauges, humidity gauges, wind speed gauges, camera and computer.

Figure 1. The pilot house at FT-UKI.

2.1. Steps of research and data collecting
1) Research is conducted on a pilot house that can be rotated in four orientation positions: (i) north-south direction, (ii) east-west direction, (iii) northeast-southwest direction, and (iv) southeast-northwest direction.
2) The observation time is in the morning at 08:30 am, and afternoon at 12:30 pm and at 17:00 pm, it also associated with a low angle and high angle of the sun.
3) Take the measurements around pilot house conditions (buildings and vegetation).
4) Shooting conditions that exist in and around the pilot house.
5) The measuring process of temperature, air humidity, and wind speed are done at the observation time and pilot house position predetermined in number one above.
6) The measuring point is selected in the front, middle and rear in the pilot house.
7) Measurements were performed for each point simultaneously carried out by:
   - Put the sensors/gauges at each observation point in turn.
   - every measurement at each sensor point left to advance to the numbers on the LCD screen of gauges become likely to stable.
   - after unchanging, the numbers are recorded, and performed at the next measurement point until completion.

2.2. Data analysis
Data analysis and calculations taken by SNI 03-0000.1-2001 [2] for thermal comfort and the measurement point used in the thermal comfort research is the point on the front, middle and rear in the pilot house.

The general model for the data analysis used to see the effect of temperature, relative humidity and wind speed at this time; each will use a randomized block design [13].

\[ Y_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij} \]

Where:
- \( Y_{ij} \) = the magnitude of temperature/air humidity/wind speed
- \( \mu \) = the average temperature/relative humidity/air speed
- \( \tau_i \) = the effect of building orientation
- \( \beta_j \) = time influence
- \( \epsilon_{ij} \) = error

3. Result and discussion
To make a planning and conduct of good building, conditions of local climatic need to be noticed namely:
- the factors that might affect the comfort, mental and physical abilities of the occupants (solar radiation, temperature and its changing, rainfall, humidity, air movement and air pollution).
- the factors that might affect the safety of buildings (earthquake, storm, heavy rains and floods, tidal wave and biohazard).
- any factor that may cause damage to buildings and cause deterioration of building materials early (factor that it was mentioned on grain b, a strong intensity of the sun, a high of air humidity and condensation, dust storms and sand, as well as the content of salt in air).

Research analysis for condition of thermal comfort at FT-UKI pilot house done at 08:30 am, at 12:30 pm and at 17:00 pm. In each direction of building orientation, observations made during 10 working days (2 weeks), then the pilot house will be rotated to match of the next building orientation. This is done until the whole building orientation is reached, wherein the first week of orientation east - west, the second week of northeast - southwest, the third week of the north - south, and the fourth week of southeast - northwest. The building orientation has always been associated with thermal comfort and building energy usage. Building orientation east - west in this research means that the front and rear of the pilot house building of FT-UKI facing toward the east and west.

3.1. Air temperature
The results showed that when the building orientation to the north - south at 08:30 am in the morning, the air temperature ranges between 30.0 – 32.8°C. For the same hour when the building orientation to the east -
west, the air temperature ranges between 28.1 – 31.6°C. While the temperature on the building orientation to the northeast - southwest is 29.0 – 30.6°C; and air temperature for the building orientation to the southeast - northwest is 28.2 – 30.0°C (Figure 2). On the average, the highest temperature in the pilot house at FT-UKI at 08:30 am match the building orientation to the north to the south, and the lowest were in the building orientation to the southeast - northwest.

For the building orientation to the north - south at 12:30 pm, the air temperature ranges between 36.9 – 39.4°C. At the same time when the building orientation to the east - west, the air temperature ranges between 35.0 – 38.7°C. While the temperature on the building orientation to the northeast - southwest is 35.1 - 39.3°C; and air temperature for the building orientation to the southeast - northwest is 36.1 – 38.2°C (Figure 3). On the average, the highest temperature in the FT-UKI pilot house at 12:30 pm found on the building orientation to the north - south, and the lowest were on the building orientation to the east - west.

Figure 2. Air temperature in FT-UKI pilot house at 08.30 am

Figure 3. Air temperature in FT-UKI pilot house at 12.30 pm
Air temperature for the building orientation to the north-south at 17.00 pm ranged between 36.0 – 38.0°C. At the same time when the building orientation to the east-west, the air temperature ranges between 31.0 – 37.7°C. While the temperature on the building orientation to the northeast-southwest are 34.8 – 37.0°C; and air temperature to the building orientation to the southeast-northwest is 34.6 – 37.3°C (Figure 4). On the average, the highest temperature in the FT-UKI pilot house at 17.00 pm found on the building orientation to the north-south, and the lowest were in the building orientation to the east-west. The results showed that the building orientation of the FT-UKI pilot house to the north-south direction has the hottest ambient temperatures than others. This is due to the widest field of the building facing toward the east-west, so that the room temperature becomes hotter than when the building orientation facing a different direction. Meanwhile, the building orientation to the east-west has the lowest room temperature, especially during afternoon.

In general it can be said that the air temperature in the room of FT-UKI pilot house does not meet the requirements of thermal comfort. For humid tropical climate, thermal comfort is achieved at the boundary 24°C < T < 26°C [17]. Similarly, the thermal comfort standards according to ISO standard 03-0000.1-2001 forget is 20.8°C < T < 27.1°C [17]. So to meet the standards of thermal comfort at FT-UKI pilot house needed air conditioning.

Table 1. Analysis of variance from room temperature on building orientation and observation time in the pilot house at FT-UKI.

| Source of variance | Sum of squares | Degree of free | Midle square | F count | F table (0.05/001) |
|--------------------|---------------|----------------|--------------|---------|-------------------|
| Building orientation | 123.57        | 3              | 41.19        | 158.42**| 4.76/9.78         |
| Observation time   | 7.56          | 2              | 3.78         | 14.54** | 5.14/10.92        |
| Error              | 1.54          | 6              | 0.26         |         |                   |
| Total              | 132.67        | 11             |              |         |                   |

**significant to level of α(0.01)
The analysis of variance results for the air temperature in the pilot house at FT-UKI, can be seen in Table 1. Table 1 shows that the direction of the building orientation has greatly affect to the temperature of the room in a project house at FT-UKI. Likewise with the observation time (morning and afternoon) also affects the air temperature in the room at a pilot house at FT-UKI. The F-count results larger than F-table indicates that the data obtained is very clearly supports that the building orientation and the observation time affects the air temperature in the room at pilot house at FT-UKI (Table 1). According to Karyono [10], building orientation also take a significant effect to help the house to be comfortable as not much direct solar radiation penetrating the house. Measuring indoors and outdoors temperatures during day hours it was found that between 8 am and 4 pm indoors temperature was always lower than the outdoors. The indoor temperatures could achieve up to 4°C lower than the outdoor during midday. This is a good example in terms of low energy design, in which without installing AC this house could be comfortable.

3.2. Air humidity

Indonesia is in the humid tropics, with features such as: high air humidity and air temperature are always hot throughout the year. The average air humidity is about 80%, will reach a maximum at around 06.00 am and minimum at 14.00 pm. Air humidity is almost equal to the lower mainland, and the average temperature of around 32°C. The influence of air humidity on the comfort room was not as big as the effect of air temperature. Nevertheless, in this research measured indoor humidity to determine the effect of the building orientation.

The results showed that when the building orientation to the north - south at 08.30 am in the morning, the air humidity ranged from 55.0 to 63.0%. For the same hour when the building orientation to the east - west, the air humidity ranged from 59.1 to 79.0%. While the air humidity on the building orientation to the northeast - southwest is 44.2 to 70.3%; and air humidity to building the orientation to the southeast - northwest is 58.1 to 70.8% (Figure 5). On average, the highest air humidity in the FT-UKI pilot house at 08:30 am match the building orientation to the east - west and the lowest were in the building orientation to the north - south.

![Figure 5. Air humidity in FT-UKI pilot house at 08.30 am](image)

Air humidity to the building orientation to the north - south at 12:30 pm, ranged from 33.0 to 59.3%. At the same time when the building orientation to the east - west, the air humidity ranged from 32.8 to 72.2%. While the air humidity on the building orientation to the northeast - southwest was 32.5 - 44.0%; and air humidity to the building orientation to the southeast - northwest is 32.9 to 44.0% (Figure 6). On average,
the highest air humidity in the FT-UKI pilot house at 12:30 pm found on the building orientation to the east - west and the lowest were in the building orientation to the northeast - southwest.

![Figure 6. Air humidity in FT-UKI pilot house at 12.30 pm.](image)

For the building orientation to the north - south at 17.00 pm, the air humidity ranged from 44.0 to 54.5%. At the same time when the building orientation to the east - west, the air humidity ranged from 45.0 to 67.0%. While the air humidity on the building orientation to the northeast - southwest is 40.5 to 52.0%; and air humidity to the building orientation to the southeast - northwest is 40.8 to 49.6% (Figure 7). On average, the highest air humidity in the FT-UKI pilot house at 17.00 pm found on the building orientation to the east - west and the lowest were in the building orientation to the southeast - northwest.

![Figure 7. Air humidity in FT-UKI pilot house at 17.00 pm](image)

From the air humidity data in this research, it was found that the air humidity in the pilot house at FT-UKI showed the lowest in the orientation towards east - west; either in the morning until late afternoon. Meanwhile, the highest air humidity turned out differently; for the morning encountered on orientation to the north - south; noon (12.30 pm) on orientation to the northeast - southwest; and in the afternoon
encountered on orientation to the southeast - northwest. Data of air humidity indoor in pilot house at FT-UKI obtained from this research meet the standard recommended of air humidity ranging between 40% - 70%.

The analysis of variance results for air humidity in the pilot house at FT-UKI, can be seen in Table 2. Table 2 shows that the direction of building orientation greatly affect the air humidity room/indoor in a pilot house at FT-UKI. Likewise with the observation time (morning and afternoon) also affect the air humidity indoor in the pilot house at FT-UKI, although not as large as the effect of building orientation. Results of F-count larger than F-table indicates that the data obtained is very clearly supports that the building orientation and the observation time affects the air humidity of the room in pilot house at FT-UKI.

Table 2. Analysis of variance of moisture on building orientation and observation time in the pilot house at FT-UKI.

| Source of variance | Sum of squares | Degree of freedom | Mean square | F count | F table (0,05/001) |
|-------------------|---------------|------------------|-------------|---------|-------------------|
| Building orientation | 1041.92 | 3 | 347.31 | 39.65** | 4.76/9.78 |
| Observation time | 153.76 | 2 | 76.88 | 8.78* | 5.14/10.92 |
| Error | 52.54 | 6 | 8.76 | | |
| Total | 1248.22 | 11 | | | |

**significant to level of α (0,01)

3.3. Air movement (wind speed)
The results showed that when the building orientation to the north - south at 08.30 am in the morning, the wind speed ranged between 0.2 - 0.5 m/sec. At the same hour when the building orientation to the east - west, the wind speed ranged also between 0.2 - 0.5 m/sec. Meanwhile the wind speed on the building orientation to the northeast - southwest was 0.4 - of 0.7 m/sec; and wind speed to the building orientation to the southeast - northwest is 0.3 to 0.8 m/sec (Figure 8). On average, the highest wind speeds in the FT-UKI pilot house at 08:30 am match the building orientation to the southeast - northwest, and the lowest were in the building orientation to the north - south.

For the building orientation to the north - south at 12:30 pm, the wind speed ranged between 0.2 – 1.1 m/sec. At the same time when the building orientation to the east - west, the wind speed ranging from 0.3 - 1.2 m/sec. Meanwhile the wind speed in the building orientation to the northeast - southwest is 0.5 - 1.2 m/sec; and wind speed to the building orientation to the southeast - northwest is 0.5 - 1.5 m/sec (Figure 9). On average, the highest wind speeds in the FT-UKI pilot house at 12:30 pm found on the building orientation to the southeast - northwest and the lowest were in the building orientation to the north - south.

The research results also showed the wind speeds for building orientation to the north - south at 17:00 pm, ranging from 0.3 - 1.2 m/sec. At the same time when the building orientation to the east - west, the wind speed ranged between 0.3 – 1.1 m/sec. Meanwhile the wind speed on the building orientation to the northeast - southwest is 0.5 – 1.1 m/sec; and wind speed to the building orientation to the southeast - northwest is 0.6 - 1.4 m/sec (Figure 10). On average, the highest wind speed in the FT-UKI pilot house at 17:00 pm found on the building orientation to the southeast - northwest, and the lowest were in the building orientation to the north - south.
Figure 8. Wind speed in FT-UKI pilot house at 08.30 am

Figure 9. Wind speed in FT-UKI pilot house at 12.30 pm

Of the overall wind speed data in this research, it was found that the wind speed in the pilot house at FT-UKI lowest in the orientation towards the north-south; either in the morning and afternoon. Meanwhile, the highest wind speed encountered on orientation to the southeast-northwest; either in the morning and afternoon. From the analysis of variance for the pilot house at FT-UKI, are shown in Table 3. Table 3 shows that the direction of building orientation greatly affects the wind speed in the pilot house at FT-UKI. Likewise with the observation time (morning and afternoon) also affect the wind speed in the pilot house at FT-UKI, although not as large as the building orientation effect. The F-count results larger than F-table indicates that the data obtained is very clearly supports that the building orientation and the observation time affect the wind speed in pilot house at FT-UKI.
Figure 10. Wind speed in FT-UKI pilot house at 17.00 pm

Table 3. Analysis of variance of wind speed on building orientation and observation time in the pilot house at FT-UKI.

| Source of variance | Sum of squares | Degree of free | Midle square | F count | F table |
|--------------------|----------------|----------------|--------------|---------|---------|
| Building orientation | 0.32           | 3              | 0.107        | 21.4** | 4.76/9.78 |
| Observation time    | 0.07           | 2              | 0.035        | 7.0'    | 5.14/10.92 |
| Error               | 0.03           | 6              | 0.005        |         |         |
| Total               | 0.42           | 11             |              |         |         |

**significant to level of α (0.01)

Generally, research related to building comfort is carried out by observation variables such as sun shading, air ventilation, building wide standards, building materials and comfort for residents such as heat radiation, convection, evaporation and conduction. Meanwhile, in doing an activity, such as sitting, typing, drawing, sleeping, and so forth, humans with a certain body size require space with a certain size of space called space. In order for the activity to work properly, the space used for the movement must have sufficient dimensions or in accordance with the size of the body and space of motion [3, 6, 12].

The observations made for this research are temperature, humidity and air velocity in the four orientation directions of the sample house (north - south, east - west, southeast - northwest, southwest - northeast) at 08.30 am, at 12.30 pm and at 17.00 pm, and focuses its merits on all four directions of the orientation. With the result of the average calculation of observation of temperature, humidity and air velocity at this pilot house will be known orientation direction which near the standard of FT-UKI pilot house comfort of and comfort of its occupant.

The results showed the best building orientation position is found in northwest-southeast direction with a temperature of 32°C, air humidity 60% and wind speed of 0.8 m/sec, although this is not a condition that meets the regulatory standards. Thus, naturally, the four-way building orientation position predicted by previous researchers conducted with various variables when compared with the comfort regulation standard theory of the Indonesian National Standardization Agency, especially in buildings in humid tropics,
temperature regulation treatment, utilization of the surrounding environment and surrounding environment engineering cannot be used as a measure anymore. This condition is generally caused by the quality of the surrounding environment is decreased by the world global warming influence. In this case, there is a need for concerted efforts (artificially) to engage in green engineering and sustainable building technology engineering in a continuous proportion.

4. Conclusions
The research results on measurement of the average temperature, humidity and wind velocity shows the space comfort tendency in the direction of orientation building northwest - southeast. Thus other factors such as the space volume, the openings width on the walls, the material types use, shadow patterns and vegetation around the building for the position of both directions orientation can easily optimize the comfort space in the building. This can be a consideration of the design of the building in both position orientation directions when combined with other factors.

5. References
[1] ASHRAE 1992 Thermal Environmental Conditions for Human Occupancy Standard 55-1992 American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, USA
[2] Badan Standardisasi Nasional (National Standardization Agency) 2001 SNI: Procedures for Design of Ventilation and Air Conditioning System in Building BSN Jakarta
[3] Brown, R D and T J Gillespie 1995 Microclimate Landscape Design, Creating Thermal Comfort and Energy Efficiency John Wiley and Sons Inc New York
[4] Carlucci, S 2013 Thermal Comfort Assessment of Buildings Springer DOI: 10.1007/978-88-470-5238-3
[5] Department of Public Works 2006 Building Technical Requirements Guidelines. Office of Building Management and Local Government Building Jakarta
[6] Fergus Nicol, Michael Humphreys, and Susan Roaf 2016 Adaptive Thermal Comfort: Foundation and Analysis Routledge London
[7] Feriadi, H and Wong N H 2002 “Thermal Comfort for Naturally Ventilated Houses in Indonesia”, in Proceedings of International Conference Buildings Research and the Sustainability of the Built Environment in the Tropics Tarumanagara University Jakarta, 14-16 October 2002
[8] Haruna, I U, I Musa, M I Tikau and M Yerima 2014 “Improvement of Thermal Comfort In Residential Buildings” International Journal of Scientific and Technology Research, Vol 3 Issue 3, March 2014, pp 180-183
[9] Karyono, T H 2000 Report on Thermal Comfort and Building Energy Studies in Jakarta Journal of Building and Environment, vol 35, pp 77-90, Elsevier Science Ltd, UK
[10] Karyono, T H 2010 “The Relationship between building design and indoor temperatures: A case study in three different buildings in Indonesia”, Proceedings 6th Windsor Conference: Adapting to Change: New Thinking on Comfort and Energy Use in Buildings (Windsor-London, UK, 9-11 April 2010) http://nceub.org.uk
[11] K Parsons 2010 “Thermal Comforts in Buildings” in M Hall (editor), Materials for Energy Efficiency and Thermal Comfort in Buildings Woodhead Publishing p:127-147 DOI: https://doi.org/10.1533/9781845699277.1.127
[12] Ken Parsons 2014 Human Thermal Environments: The Effects of Hot, Moderate, and Cold Environments on Human Health, Comfort, and Performance (Third Edition) CRC Press New York
[13] Mendenhall, W, R J Beaver, and B M Beaver 2013 Introduction to Probability and Statistics (14th edition) Brooks/Cole Cengage Learning Boston
[14] Mom, C P 1947 The Application of the Effective Temperature Scheme to the Comfort Zone in the Netherlands Indies, Chronica Naturae, Vol 103
[15] Nugroho, M A 2011 A Preliminary Study of Thermal Environment in Malaysia’s Terraced Houses, Journal and Economic Engineering: 2(1), 25-28
[16] Peeters, L, R Dear, J Hensen and W D’haeseleer 2009 “Thermal Comfort in Residential Buildings: Comfort Values and Scales for Building Energy Simulation” Applied Science, Vol 86, issue 5, May 2009m p:772-780 Elsevier DOI: https://doi.org/10.1016/j.apenergy.2008.07.011
[17] Satwiko, P 2008 Building Physics Andi Publisher Yogyakarta
[18] Sedki, A, N Hamza, and T Zaffagnini 2013 “Effect of Orientation on Indoor Thermal Naturally in Winter Season in Hot Arid Climates, Case Study: Residential Buildings in Greater Cairo” IACSIT International. Journal of Engineering and Technology, Vol 5 (6) December 2013 p:712-716
[19] Sugini 2007 “Indoor Climatic Variables and the Bias of Thermal Comfort Index of PMV in Warm Humid Climate with A Specific Reference of Yogyakarta, Indonesia” in Proceedings of the 8th International Conference ‘Sustainable Environmental Architecture: Sustainability in Rain, Sun and Wind’, Petra University, Surabaya, 23-14 August 2007
[20] UN Habitat, 2015, Sustainable Building Design for Tropical Climates UN Habitat, Nairobi - Kenya