# Simulation of Thermal Comfort of Heritage Residential House in Bandung using Computational Fluid Dynamic

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**Abstract.** Global Warming is a worldwide issue because it occurs in almost all countries including Indonesia. To anticipate this issue, since the last few years the Green Architecture concept has been established in Indonesia. One of the impacts of implementing this concept is caring for the health of occupants by maintaining air quality and thermal comfort indoors adhering to sustainable principles. Buildings built during the Dutch Colonial period were considered to have paid attention to thermal comfort for their occupants due to Indonesia's tropical climate that is too hot for those who come from a country with 4 seasons. This paper aims to study the potential of ex-Colonial residential buildings in terms of thermal comfort by studying or analyzing indoor airflow patterns in order to obtain building designs that meet the Thermal Comfort requirements that can be applied to present-day building designs. Quantitative analysis methods are used based on weather measurement data and existing comfort conditions in the field, calculations, and simulations using Computational Fluid Dynamic (CFD) models. The research problem is how the architectural design of colonial buildings adapted to tropical climates? How is the thermal comfort produced in ex-colonial buildings? Analysis of flow patterns in the room will be carried out using the Computational Fluid Dynamic (CFD) method using the Flovent program. In this study, data collection in the field included room conditions (room geometry, materials and equipment specifications used), air conditions (air flow velocity, temperature, humidity) and solar radiation on the research object. In terms of typology and design, ex-colonial buildings for Dutch, Indo-Dutch and indigenous peoples have the potential to fulfill these requirements so that they can be used as a reference and applied to present-day building designs, both those that have been built or those that will be built.
**Keywords:** *Global warming*, *Indische Architectuur*, *thermal comfort, Computational Fluid Dynamic (CFD).*

## 1. INTRODUCTION

Indonesia lies between 2 continents; Asia and Africa and 2 oceans: Indian and Pacific which have an influence on the climate, which is tropical with high rainfall and humidity. This is different from the Netherlands which is located on the European continent which has 4 seasons. This condition was a very basic consideration for the Dutch Colonial Government when constructing buildings as places for their activities, such as residences, offices, factories, schools and other public buildings in order to obtain thermal comfort. This makes the architectural style of Colonial buildings look different from traditional Indonesian buildings which have indeed adapted to the tropical climate.

Colonial buildings generally have steep roofs (45 degrees or more) so that they can accommodate more air and rainwater can flow quickly. These buildings have a ceiling height of more than 3.5 meters with ventilation holes above the windows and at the bottom of the room. This allows air circulation in the room. In addition, the building has large door and window openings which are expected to allow maximum volume of air to enter.

The Colonial Government as the ruler of the city at that time, determined the cooler northern area of Bandung city as the center of the Dutch community. The layout and orientation of the building are adjusted to the direction of the sun and air flow so that optimal thermal comfort is obtained. In addition, cost is not an issue, so the size and quality of the material are used in the most excellent way to produce thermal comfort, strong and sturdy building that can last until today. Currently Bandung city government has designated 6 Cultural Heritage areas in the city of Bandung which can still be identified from the shape and architectural style of the buildings.

The air flow system in buildings has a very important role in controlling temperature, humidity, and quality of air movement. In order to produce a good and ideal distribution of flow, humidity and air temperature in a room, it is necessary to analyze the nature and pattern of the flow as well as the distribution of air in the room. In this study, the Computational Fluid Dynamic (CFD) method is used which is a numerical analysis using volume control as an element of the integration of equations based on mass, energy and momentum balances. These equations are solved simultaneously using the Flovent program.

Based on this, the specific objective of this study is to look at the potential for thermal comfort in 3 types of ex-Dutch colonial buildings which can later be applied to present-day building design either those that have been built or those that will be built.

The formulation of the problem which is used as the basis of research is:

- What is the pattern of airflow including temperature distribution and airflow velocity in the 3 types of ex-Dutch colonial buildings?
- What are the visualization characteristics, direction and speed as well as the pattern or distribution of airflow, temperature distribution, air humidity and wind speed in 3 types of ex-Dutch colonial buildings by simulating using CFD?
- What are the strategies and design recommendations to obtain ideal conditions as an evaluation of the thermal comfort requirements of a building?

This research aims to:

- Know and identify air flow patterns which include temperature distribution and air flow velocity in 3 types of ex-Dutch colonial buildings.
- Knowing the visualization characteristics of the direction and speed as well as the pattern or distribution of air flow, temperature distribution, air humidity and wind speed in 3 types of ex-Dutch colonial buildings, through CFD simulations.
- Looking at the potential of 3 types of ex-Dutch colonial buildings as examples of buildings that meet the requirements for thermal comfort that can be applied to present-day buildings design, either those that have been built or those that are to be built.

## 2. METHODOLOGY

The research location is ex Colonial residential building in Bandung city which includes 3 types based on its designation, namely: Dutch, Indo-Dutch and native Indonesian residents. The research uses both qualitative and qualitative analysis methods. The quantitative analysis method applied is based on direct measurement of weather data in the field using measuring instruments, calculations and model simulations.

The research began with data collection in the field and simulations using CFD with the Flovent program. Data collection in the field includes: 1) data collection on the geometry of the room, materials and specifications of the equipment used; 2) direct observation of the research object, 3) measuring airflow velocity, measuring air temperature, measuring air humidity and the level of lighting or solar radiation on the research object.

Direct measurement of weather data in the field using measuring devices includes environmental/external and building internal factors that affect the acquisition of thermal comfort, namely air temperature using a thermometer, air humidity using a humidity meter, wind speed using an anemometer, including thermal radiation using a solar power meter whenever possible. Temperature and humidity measurements are taken at 3 points in the building.

The research variable includes two main phases, namely natural and mechanical ventilation (location of inlet and outlet; air circulation path between inlet and outlet; air movement pattern) and Thermal Comfort (Calculation of room temperature; Air velocity and humidity), whereas the neglected research variables include user activity level; user clothing and layout and dimensions of furniture). The stages of the research are as follows:

- Direct observation and field documentation
- Measurement of thermal comfort elements in the field
- Processing of thermal comfort data in the field
- 3D digital model simulation using CFD software.
- Processing of 3-dimensional digital model simulation results of CFD software
- Weighting (conversion of qualitative analysis into quantitative)

One of the ex-colonial buildings that became the object of this study was Apotek Aranza Building (Figure 1), which is located on Jalan Rangga Gading no. 4 Bandung, Bandung Wetan, West Java.


**FIGURE 1.** Apotek Aranza Building

## 3. RESULT & DISCUSSION

The research was conducted in 3 (three) designs of ex Colonial residential building in Bandung city, namely: Dutch, Indo-Dutch and native Indonesian residents. Temperature and humidity data collection was carried out on 29 – 31 October 2022 for Dutch residents and 11 – 14 November 2022 for Indo-Dutch and native Indonesian residents. The Dutch resident plan is shown in Figure 2. The results of the observations can be seen in Table 1 to Table 3, while the temperature and humidity profiles of are shown in Figure 3 and Figure 4.

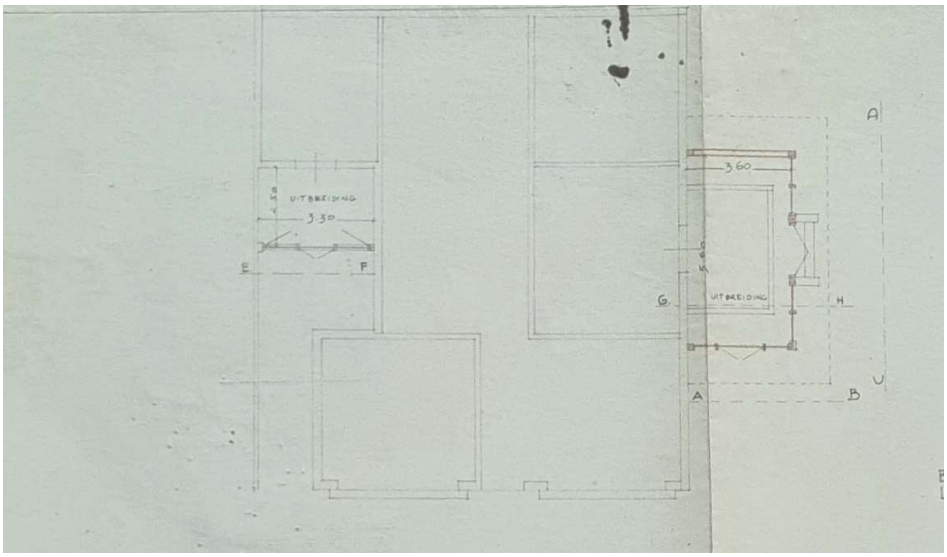


**FIGURE 2**. Apotek Aranza (Dutch resident) Plan

**TABLE 1.** Temperature and Humidity Distribution in Dutch Resident

| Dutch Resident, Point 1 | | | | Dutch Resident, Point 2 | | | | Dutch Resident, Point 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Temperature°C | Humidity%RH | Date | Time | Temperature°C | Humidity%RH | Date | Time | Temperature°C | Humidity%RH |
| 29 October 2022 | 00:03:01 | 26.5 | 65.8 | 29 October 2022 | 00:13:39 | 27.7 | 66.0 | 29 October 2022 | 00:24:25 | 27.0 | 66.0 |
| | 03:03:01 | 24.3 | 71.0 | | 03:13:39 | 25.2 | 72.7 | | 03:09:25 | 25.4 | 70.1 |
| | 06:03:01 | 23.9 | 76.2 | | 06:13:39 | 22.2 | 81.8 | | 06:09:25 | 24.5 | 73.0 |
| | 09:03:01 | 25.6 | 69.4 | | 09:13:39 | 25.6 | 69.4 | | 09:09:25 | 25.7 | 68.4 |
| | 12:03:01 | 28.2 | 59.3 | | 12:13:39 | 27.7 | 61.5 | | 12:09:25 | 28.0 | 60.0 |
| | 15:03:01 | 28.8 | 58.9 | | 15:13:39 | 28.5 | 59.9 | | 15:09:25 | 28.2 | 60.0 |
| | 18:03:01 | 27.2 | 65.5 | | 18:13:39 | 27.0 | 65.4 | | 18:09:25 | 27.1 | 65.2 |
| | 21:03:01 | 26.3 | 69.7 | | 21:13:39 | 26.4 | 68.8 | | 21:09:25 | 26.5 | 69.2 |
| 30 October 2022 | 00:03:01 | 25.8 | 71.8 | 30 October 2022 | 00:13:39 | 26.1 | 70.0 | 30 October 2022 | 00:09:25 | 26.2 | 70.3 |
| | 03:03:01 | 24.6 | 74.7 | | 03:13:39 | 25.8 | 71.8 | | 03:09:25 | 25.9 | 70.8 |
| | 06:03:01 | 23.8 | 75.4 | | 06:13:39 | 25.3 | 72.6 | | 06:09:25 | 25.5 | 71.3 |
| | 09:03:01 | 25.3 | 68.9 | | 09:13:39 | 25.7 | 67.9 | | 09:09:25 | 25.9 | 67.4 |
| | 12:03:01 | 27.8 | 59.2 | | 12:13:39 | 28.5 | 55.4 | | 12:09:25 | 28.5 | 55.5 |
| | 15:03:01 | 27.8 | 60.7 | | 15:13:39 | 28.9 | 55.6 | | 15:09:25 | 28.6 | 56.4 |
| | 18:03:01 | 26.9 | 67.2 | | 18:13:39 | 27.7 | 63.1 | | 18:09:25 | 27.3 | 64.6 |
| | 21:03:01 | 26.1 | 74.1 | | 21:13:39 | 27.2 | 68.9 | | 21:09:25 | 27.0 | 69.9 |
| 31 October 2022 | 00:03:01 | 24.6 | 77.1 | 31 October 2022 | 00:13:39 | 26.4 | 72.5 | 31 October 2022 | 00:09:25 | 26.7 | 71.0 |
| | 03:03:01 | 23.5 | 78.8 | | 03:13:39 | 26.0 | 71.4 | | 03:09:25 | 26.3 | 69.8 |
| | 06:03:01 | 22.6 | 79.4 | | 06:13:39 | 25.7 | 71.0 | | 06:09:25 | 26.0 | 69.8 |
| | 08:33:01 | 24.9 | 71.4 | | 07:49:15 | 25.6 | 72.3 | | 08:09:25 | 25.8 | 70.1 |

**TABLE 2.** Temperature and Humidity Distribution in Indo-Dutch Resident

| Indo-Dutch Resident, Point 1 | | | | Indo-Dutch Resident, Point 2 | | | |
|---|---|---|---|---|---|---|---|
| Date | Time | Temperature°C | Humidity%RH | Date | Time | Temperature°C | Humidity%RH |
| 11-Nov-22 | 13:30:55 | 25.8 | 82.0 | 11-Nov-22 | 13:32:26 | 26.4 | 83.7 |
| | 15:30:55 | 25.7 | 81.3 | | 15:32:26 | 26.1 | 78.0 |
| | 18:30:55 | 24.0 | 87.5 | | 18:32:26 | 24.1 | 83.4 |
| | 21:30:55 | 23.3 | 91.3 | | 21:32:26 | 23.5 | 87.3 |
| 12-Nov-22 | 00:30:55 | 22.7 | 91.5 | 12-Nov-22 | 00:32:26 | 23.1 | 86.6 |
| | 03:30:55 | 22.2 | 92.1 | | 03:32:26 | 22.8 | 86.8 |
| | 06:30:55 | 22.2 | 92.0 | | 06:32:26 | 22.7 | 87.7 |
| | 09:30:55 | 23.5 | 89.8 | | 09:32:26 | 23.9 | 86.8 |
| | 12:30:55 | 24.7 | 86.9 | | 12:32:26 | 24.7 | 85.9 |
| | 15:30:55 | 24.4 | 92.7 | | 15:32:26 | 24.4 | 91.5 |
| | 18:30:55 | 23.8 | 91.7 | | 18:32:26 | 23.7 | 90.3 |
| | 21:30:55 | 23.3 | 93.7 | | 21:32:26 | 23.4 | 91.3 |
| 13-Nov-22 | 00:30:55 | 22.7 | 93.3 | 13-Nov-22 | 00:32:26 | 22.9 | 90.6 |
| | 03:30:55 | 22.2 | 93.8 | | 03:32:26 | 22.6 | 89.6 |
| | 06:30:55 | 22.2 | 93.5 | | 06:32:26 | 22.7 | 90.5 |
| | 09:30:55 | 23.2 | 92.9 | | 09:32:26 | 23.7 | 89.3 |
| | 12:30:55 | 23.7 | 93.5 | | 11:14:26 | 23.9 | 92.2 |
| | | | | | | | |
| 13-Nov-22 | 11:15:55 | 23.7 | 95.0 | 13-Nov-22 | 11:17:26 | 23.9 | 92.3 |
| | 12:00:55 | 23.8 | 95.3 | | 12:02:26 | 24.1 | 92.1 |
| | 15:00:55 | 24.0 | 93.9 | | 15:02:26 | 24.1 | 92.2 |
| | 18:00:55 | 23.5 | 93.7 | | 18:02:26 | 23.5 | 92.4 |
| | 21:00:55 | 23.0 | 95.4 | | 21:02:26 | 23.1 | 92.9 |

**TABLE 3.** Temperature and Humidity Distribution in native Indonesian Resident

| Native Indonesian resident | | | |
|---|---|---|---|
| **Date** | **Time** | **Temperature°C** | **Humidity%RH** |
| 11-Nov-22 | 13:34:28 | 25.9 | 80.5 |
| | 15:34:28 | 25.9 | 78.3 |
| | 18:34:28 | 22.1 | 99.0 |
| | 21:34:28 | 22.6 | 93.1 |
| 12-Nov-22 | 00:34:28 | 22.0 | 92.6 |
| | 03:34:28 | 21.7 | 92.9 |
| | 06:34:28 | 21.9 | 93.1 |
| | 09:34:28 | 23.9 | 86.5 |
| | 12:34:28 | 25.5 | 82.7 |
| | 15:34:28 | 23.3 | 100.0 |
| | 18:34:28 | 22.6 | 100.0 |
| | 21:34:28 | 22.0 | 100.0 |
| 13-Nov-22 | 00:34:28 | 21.5 | 100.0 |
| | 03:34:28 | 21.3 | 99.1 |
| | 06:34:28 | 22.0 | 99.2 |
| | 09:34:28 | 23.8 | 97.7 |
| | 11:16:28 | 23.0 | 100.0 |
| | | | |
| 13-Nov-22 | 11:19:28 | 23.1 | 100.0 |
| | 12:04:28 | 23.2 | 100.0 |
| | 15:04:28 | 22.9 | 94.2 |
| | 18:04:28 | 22.3 | 93.6 |
| | 21:04:28 | 21.9 | 93.7 |
| 14-Nov-22 | 00:04:28 | 22.1 | 93.8 |
| | 03:04:28 | 21.6 | 93.8 |
| | 06:04:28 | 21.4 | 100.0 |
| | 09:04:28 | 23.6 | 99.1 |
| | 12:04:28 | 25.1 | 96.5 |
| | 12:34:28 | 25.4 | 96.9 |

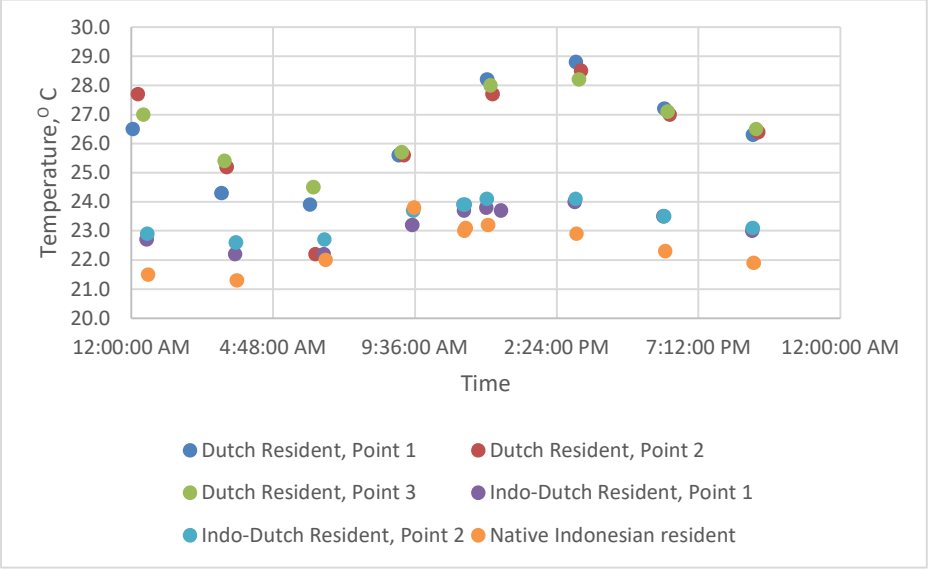


**FIGURE 3.** Temperature Profile in Dutch, Indo-Dutch and Native Indonesian Residents

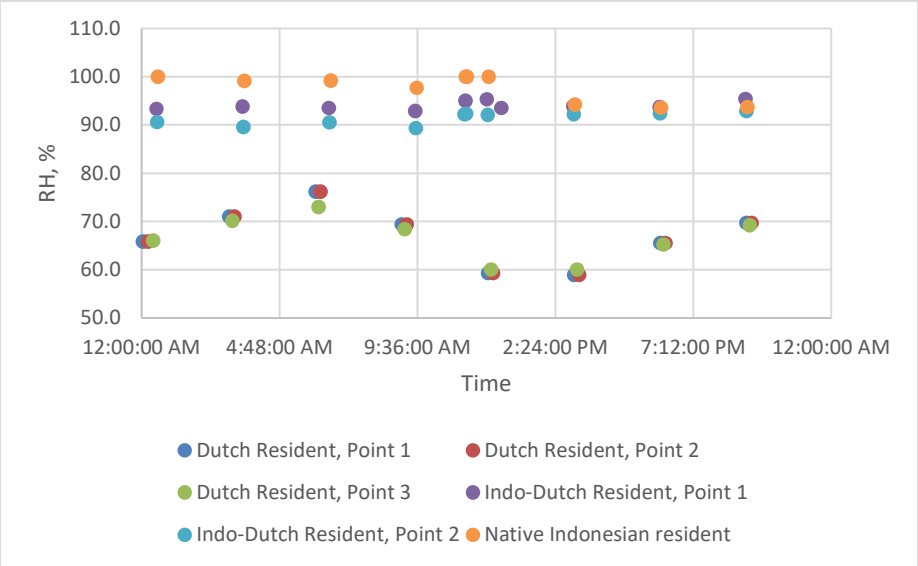


**FIGURE 4.** Humidity Profile in Dutch, Indo-Dutch and Native Indonesian Residents

## CONCLUSION

It can be concluded that type of Dutch Resident which meets the thermal comfort requirements. In order to get a good model for other types of ex-colonial building, it is necessary to simulate using CFDs based on Dutch Resident type Building.

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