Thermal reduction at the Atmowikoro House as the Javanese-Indische building in Laweyan

N N Larasati¹, W Setyaningsih¹, and Y Winarto¹

¹Architecture Program, Faculty of Engineering, Universitas Sebelas Maret Jl. Ir. Sutami 36A Surakarta 57126, Jawa Tengah, Indonesia

Corresponding author’s email: nisrinacece@gmail.com

Abstract. Climate is one of the most important factors to consider in house design. Climate in Indonesia has a relatively hot air temperatures, high solar radiation and high humidity. Javanese-Indische building is one of the architectural products of the past having a high quality of adaptability to the Indonesian environment. The application of the Javanese space and the colonial form created buildings in Laweyan as the best architectural description of its time. This article is intended to reveal thermal performance in one of the Javanese-Indische buildings in Laweyan, the Atmowikoro house built in 1818. The aim of the study is to review the extent to which climate considerations in building a Javanese-Indische house were carried out by the Laweyan people at that time. The method employed was the quasi-experimental method using Ecotect software to take thermal measurements of Atmowikoro buildings. Atmowikoro house has the ability to adjust the thermal movement in tropical climate. The reduction in temperature is evidenced by the presence of an average thermal difference in the environment, 3.7°C higher in the dry season and 3.8°C higher in the rainy season than that of the temperature in the building.

1. Introduction

Climate is one of the most important factors to consider in house design. Proper consideration of climate factors will directly affect building thermal performance. High temperatures become the biggest problem in tropical regions as the environment temperature remains relatively hot throughout the year which for most of the time in a year the building is "in charge" of cooling, rather than warming and the average annual temperature is not less than 20ºC [1]. The right decision then needed to be made because traditional society tends to see architecture as a study that goes in harmony with times [2].

Indische buildings arise as a form of a dilemma between architecture idealism of the Dutch and their politics [3]. They believe a building should be able to adapt to its local climate through a system modification and be able to interact with nature. Indische architecture is able to adapt to climate through a modification system causing the outside climate and inner climate to have different temperatures. These results are formed through the climate cycle in Indonesia [3]. Such phenomena happen because every building interacts with its environment.

Tropical climate regions have significant temperature changes between day and night. This happens due to the presence of hot solar radiation that enters the building in various events [3]. Changes between dry and rainy season in tropical countries directly affect the building as they exposed to direct sunlight and rain throughout the year. Treatment in the form of air ventilation holes
to form wind currents can reduce this problem. Ventilation on two sides of the building is able to flow wind in the building [4].

Laweyan is a sub-district in Surakarta City. It holds historical evidence of the arisen Javanese-Indische buildings in Indonesia. Laweyan is proof of the long last prosperity achieved by female batik merchants throughout work ethic in the competition of the Javanese Batik industry, and these phenomena become physical form of culture representing who and what their roles in the early 20th century in the system of Javanese social society [5]. Mixture of Javanese traditional spatial and colonial facade formed Javanese-Indische buildings as one of the best architecture at that time because of its adaptive characteristic to Indonesia's tropical climate. The Javanese-Indische houses are the style of mixing Javanese buildings and European buildings created from the socio-economic development of Indonesian culture. This mixing style is one of the architectural products from the past having a high quality of sustainability in adapting to the Indonesian environment.

This study aims to analyse the thermal reduction of Javanese-Indische buildings in Kampung Laweyan to identify the resilience of the Javanese-Indische building system in adjusting Indonesia's tropical climate by using cultural acculturation contained in buildings. The model used in this research was the Atmowikoro House, a Javanese-Indische building built in 1818. The purpose of the research is to review the extent to which climate considerations in building the Javanese-indische house were carried out by the Laweyan community at that time. The method employed was the quasi-experimental method using the Ecotect software to take measurements of the building thermal, radiation, air humidity and wind forming thermal comfort in the hierarchy society buildings in Laweyan.

2. Material and Methods
The research used quantitative methods. Data collection techniques were generally carried out randomly research instruments [6]. The type of quantitative method used was the quasi-experimental method. In the quasi-experimental method, the condition similar to the original condition was simulated to check the given hypotheses regarding the system in the building of a research design, and this research design specifies the examined objects more than other objects [7].

The quasi-experimental was done using a simulation process with the help of Building Information Modelling (BIM) and Autodesk Ecotect software. Simulation is a research design applied in a variety of topics, for purposes ranging from highly targeted applications in design projects to building theory. For this study, ECOTECT was used to simulate cumulative data of Atmowikoro’s inside and outside thermals monthly. This simulation can display graphic distribution patterns and the availability of thermal reduction of the entire building to determine the thermal condition of the building. Simulation with the help of Building Information Modelling (BIM) can inform every stage of the design process, including conceptual design and schematic design [7]. Numerical simulations were performed using an existing software program using a validated data. Using other modifications and calculations, the authors then compared the values obtained from the simulation model with the experimental data. This study employed simulation based on tropical climate in Indonesia occurring between dry and rainy seasons where dry seasons usually happen in March to September and rainy seasons happen in October to February.

2.1. Study of Surakarta climate conditions
The city of Surakarta is located between 110° 45"15" and 110° 45 "35" East Longitude and between 7° 36 "and 7° 56" South Latitude. Surakarta City is one of the major cities in Central Java supporting other cities such as Semarang and Yogyakarta. The temperature in Surakarta City in 2018 ranged from 22.7 ° C to 28.8 ° C while the air humidity ranged from 60 % to 88 %. Most rainy days happened in January and February totally 24 rainy days [8]. In Table 1, the lowest temperature in average was in September, namely 22.7 ° C while the highest temperature in average in December was 27.3 ° C.
Table 1. The Average Temperature in Surakarta City in 2018 (BPS Surakarta, 2019)

| Month    | Max  | Min  | Average |
|----------|------|------|---------|
| January  | 28.5 | 19.7 | 25.8    |
| February | 26.1 | 15.1 | 25.6    |
| March    | 25.8 | 14.0 | 26.8    |
| April    | 26.3 | 17.6 | 27.6    |
| May      | 28.7 | 20.6 | 28.1    |
| June     | 29.2 | 18.0 | 26.9    |
| July     | 31.7 | 21.3 | 26.0    |
| September| 24.9 | 11.1 | 26.2    |
| October  | 30.3 | 20.5 | 28.8    |
| November | 25.1 | 14.6 | 28.5    |
| December | 31.1 | 12.0 | 27.3    |

2.2. The Atmowikoro House
The Atmowikoro house is located in Jalan (Street) Sidoluhur No.58, Laweyan. The Atmowikoro house was built by a batik merchant named Tjokrosoemarto in 1818. As a form of a Javanese-Indische building, the Atmowikoro house still holds a complete Javanese spatial shape containing Pendapa, Pringgitan, Ndalem, Senthong, and Krobongan. This house, furthermore, has a symmetrical walls plan, which is a concept of duality of Javanese people.
This picture shows that the Atmowikoro building still has a complete spatial order of Java which symmetrically adjusts the duality system of Javanese society.

The main building material for the wall is red bricks with teak wood columns, most of which have not changed except the paint and colour of the building. The main materials used to build the house are 20cm traditional tiles, and metal ceilings. Some of the mixing elements seen in the building are the use of high ceilings and stained glass on the upper wall.

3. Results and Discussions

At the Atmowikoro House, the building temperature simulation was carried out within a year to measure the hottest day based on the time calculation from 00 a.m. to 12 a.m. WIB (western Indonesia standard time) to determine the level of thermal comfort the building can provide. Measurements were made in the simulation based on dry season in March to September and rainy season in October to February. The timing was done on the hottest day of the month to determine how the building responds to the environment through thermal conditions. In the research the highest heat achievement was at 12 p.m. to 5 p.m. while the highest cold performance was at 11 p.m. to 6 a.m.

3.1. The Dry Season

Table 2. Maximum and Minimum Thermals in Dry Season in March to September

| Month     | INSIDE (MAX) | OUTSIDE (MAX) | TEMP DIF | INSIDE (MIN) | OUTSIDE (MIN) | TEMP DIF |
|-----------|--------------|---------------|----------|--------------|---------------|----------|
| March     | 28.7         | 33.0          | -4.3     | 21.0         | 15.3          | 5.7      |
| April     | 32.2         | 35.6          | -3.4     | 24.3         | 17.3          | 7.0      |
| May       | 30.3         | 34.0          | -3.7     | 24.4         | 21.8          | 2.6      |
| June      | 23.9         | 26.1          | -2.2     | 21.3         | 18.6          | 3.7      |
| July      | 33.2         | 37.9          | -4.7     | 24.2         | 25.2          | -1.0     |
| August    | 27.7         | 32.5          | -4.8     | 21.5         | 20.2          | 1.3      |
| September | 31.3         | 34.0          | -2.7     | 24.4         | 21.8          | 2.6      |
| Mean      | **26.9**     | **33.3**      | **-3.7** | **23.0**     | **20.0**      | **3.1**  |

Table 2 presents the results of thermal simulations based on the hottest day of the month adjusting to the thermal conditions outside the building. According to the results of the study, the average of the
ambient temperature was 33.3 °C and the average building temperature was 26.9 °C. This figure shows 6.4 °C difference with a tendency to reduce building temperatures during the day. Figure 3 illustrates the movement of temperature in buildings and environment during the dry season.

![Figure 3](image)

**Figure 3.** The Graph of Atmowikoro's Maximum and Minimum Thermals in the Dry Season

In the dry season the highest temperature outside the building was 37.9 °C in July with the coldest temperature of the building was at 15.3 °C in March. Based on the simulation results, the temperatures in the building were between the hottest temperature and the coldest temperature of the environment within the range from 21 to 33.2 °C in the dry season. The coldest temperatures were in June within the range from 26.1 to 18.6 °C. According to the graph, the building tends to bring thermals into a lower degree when the temperature outside the building rises extremely and to bring thermals into a stable degree when the ambient temperature tends be extremely cold. This indicates a good air circulation in the building so that the building is able to issue heat and control the thermal in the building.

### 3.2. The Highlight of Dry Season

In the dry season there was a significant change in temperature in June which is the middle of the dry season. In the simulation on June 21, the average building temperature was 24.6 °C. In June; the building took the highest heat from 10 a.m. to 11 a.m. with the temperature of 25.5°C. The coldest temperatures were at 10 p.m. – 11 p.m. hours, namely 21.3°C. In addition, the highest gap between both temperatures that can be optimized by the building was 22°C at midnight.

![Figure 4](image)

**Figure 4.** The Graph of Atmowikoro's Thermal Movement on 21 June
The graph in Figure 4 shows that the Atmowikoro building experiences insignificant thermal changes. The time range of thermal changes is still above the range of 21-26 °C where the hottest peak is at noon. Nevertheless, at 10 a.m., the indoor temperature exceeds the outdoor temperature with a decrease below 20 °C.

Significant changes also occurred in September as the transitional month between the dry season and the rainy season in October. In September the lowest building temperature was 24.4 °C which the lowest building temperature compared to the other temperatures such as in March, June, and December. In September the building also experienced the highest inside temperature, 32 °C at 3pm. On the other hand, the highest outside temperature was 34 °C.

![Figure 5. The Graphic of the Thermal Movement of the Atmowikoro Building on 21 September](image)

Based on the Figure 5, we can see an increase in temperature in the period before 12 p.m. to 4 p.m. and a steep decrease at 4 p.m. The increase and decrease occur when the outside temperature of the building rises and gives an impact into the building. The graph shows the building passively tries to restore the normal temperature of the building, and the normal temperature can only be reached after the heat starts to decrease at 5pm.

Based on the figure 6, different results happen in March when the season changes from the rainy season to the dry season. The average temperature in March is around 21.5 °C. The table displays the indoor temperature reaches its highest temperature, 28.7 °C, when the outside temperature of the building reaches 33 °C at 2 p.m. The temperature difference between outside and inside the building at this moment is 4.3 °C. On the other hand, the building reaches the coldest temperature of 21.0 °C when the outside temperature of the building is 15.3 °C at 6a.m.

![Figure 6. The Graphic of Thermal Movement of the Atmowikoro Building on 21 March](image)
The figure 6 describes that the building tends to maintain a constant temperature when the outdoor temperature experiences a steep increase. From the graph, it can be seen that the change of temperature occurs at 4 a.m. to 12 p.m. where the previous temperature, below 20 °C, hit the point above 30 °C.

3.3. The Rainy Season

The table 3 shows that in the rainy season the average temperature outside the building reaches 36 °C and the temperature inside the building reaches 32.4°C. In the rainy season, the difference between the highest and lowest temperatures tends to be more extreme in which the outside temperature the building has an average temperature of 3.8 degrees higher than the temperature inside the building. The highest temperature occurred in October, namely 39 °C. October, furthermore, was actually the transitional period from the dry season to the rainy season making the building temperature able to reach 37.2°C while the lowest building temperature was at 17.8°C.

| Month   | INSIDE (MAX) | OUTSIDE (MAX) | TEMP DIF | INSIDE (MIN) | OUTSIDE (MIN) | TEMP DIF |
|---------|--------------|---------------|----------|--------------|---------------|----------|
| October | 37.2         | 39.0          | -1.8     | 26.2         | 28.6          | 2.4      |
| November| 28.8         | 32.0          | -3.2     | 22.4         | 17.8          | 4.6      |
| December| 31.8         | 37.0          | -5.2     | 23.4         | 19.8          | 3.6      |
| January | 30.9         | 36.5          | -5.6     | 23.7         | 24.1          | -0.4     |
| February| 33.5         | 36.9          | -3.4     | 22.8         | 17.8          | 5.0      |
| Mean    | 32.4         | 36.3          | -3.8     | 23.7         | 21.6          | 3.0      |

The figure 7 illustrates the temperature changes in the rainy season is insignificant compared to the temperature changes in the dry season. The temperature inside the building is within the range between 22.4 - 37.2 °C. In October, the lowest environmental temperature is 2.4 °C higher than the lowest building temperature. In addition, the difference in the lowest temperature between the lowest temperatures in January, both inside and outside, is minimal, namely 0.4 °C.

![Figure 7. The Graph of Atmowikoro's Maximum and Minimum Thermal in the Rainy Season](image-url)
3.4. The Highlight of Rainy Season
In December the average of building reached 22.8 °C. The figure 8 shows that in December the highest building temperature is 31.8 °C happening at 2 p.m., and in the same time the outdoor temperature reaches 37.0 °C. The highest temperature difference outside and inside the building is 5.8 °C. Based on the graph, the coldest building temperature occurs in December hitting 23.4 °C at 9 p.m. to 10 p.m.

Figure 8. The Graph of the Thermal Movement of the Atmowikoro Building on 21 December

The Figure 8 describes the Atmowikoro building is able to manage to provide a significant temperature difference inside the building when the air temperature increases at 10 a.m. – 6 p.m. outside the room. The building also is also able to manage to restore the temperature in the normal range after experiencing a surge of heat from outside.

Based on the aforementioned facts, there are differences in the outside and inside temperature. These phenomena indicate that heat was insulated before entering the building so that the building was able to reduce the temperature inside the building. There are passive attempts to optimize inside ambient temperature in the building. The Atmowikoro building manages to passively maintain the climate in the building and it can be seen from the differences between outside temperatures and temperature the room. The Atmowikoro house is able to maintain the temperature conditions in extreme external conditions in that it indirectly protects dwellers from direct changes of temperature from the outside environment.

4. Conclusions
Atmowikoro building is able to adjust the temperature changes that occur in the dry season, rainy season and the transition between the two seasons by maintaining the building temperature between the highest temperature and the lowest temperature. This house has the ability to adjust the thermal movement from outside and adjust the thermal condition of the building, hence reducing heat from outside. In dry season, Atmowikoro house is able to maintain 3.7 °C temperature lower than the outside temperature, and able to maintain 3.8 °C lower temperature in rainy season. Atmowikoro building is able to pass through the hottest point of outside temperature and restore back to normal after passing a surge of outside heat. This indicates good air circulation in the building so that Atmowikoro house is able to control heat issue. This fact indicates a good air circulation inside the building, so the building is able to release heat and control the thermal.

Based on the simulation results, it can be concluded that the building was built to passively adapt the tropical climate in Indonesia, and was managed to withstand the extreme climate. This evidence proves that the people at that time had considered climate condition in designing and constructing buildings. This community, moreover, had already known to utilize natural materials able to withstand
heat and increase thermal comfort without reducing aesthetic values contained in the Javanese-Indische architectural form.

Reference
[1] Koenigsberger O 1973 Manual of Tropical Housing and Building (London: Longman)
[2] Budihardjo E 1997 Arsitek dan Arsitektur Indonesia Menyongsong Masa Depan, Esensi Arsitektur Jawa (Yogyakarta: Andi)
[3] Hardiman G 2013 Adaptasi Bangunan Kolonial pada Iklim Tropis Lembab (Studi Kasus Bangunan Kantor PT KAI Semarang) MODUL 13 35-40 DOI: 10.14710/ml1.13.1.2013.35-40
[4] Mangunwijaya Y B 1980 Pasal-pasal Penghantaran Fisika Bangunan (Jakarta: Gramedia)
[5] Hastuti D L 2014 Kedudukan Dalem pada Program Ruang Rumah Indis Saudagar Batik Laweyan di Awal Abad Ke-20 Asintya Jurnal Penelitian Seni Budaya 6 164-75 [Online] Available at http://repository.isi-ska.ac.id/841/1/225 accessed 29-11-2019
[6] Sugiyono 2018 Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D (Bandung: Alfabeta)
[7] Groat L N and Wang D 2013 Architectural Research Methods (New York: John Wiley)
[8] BPS Surakarta 2019 Surakarta Municipality in Figures 2018 (Surakarta: BPS Surakarta)