E3S Web of Conferences **317**, 04017 (2021) https://doi.org/10.1051/e3sconf/202131704017
ICENIS 2021

What We Can Learn from Vernacular House and COVID-19 Infection? A Review of Mbaru Niang, Flores, Indonesia

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Abstract. The COVID-19 pandemic has shown that the current ventilation design, especially in residential buildings, may not provide healthy air exchange. Since current buildings in tropical climate only focused on cooling, its have become sites of rapid COVID-19 transmission. In order to avoid indoor SARS-Cov-2 transmission, some studies recommended an increase in air supply with a higher air exchange rate and to reduce the usage of the air conditioner. Flores has been designated one of the top Indonesian tourism destinations. However, access to transportation is still tricky. Analysis of local materials, culture, and weather can reduce the building cost and preserved local value to become the area's identity. Vernacular housing in Indonesia has adapted well to climatic conditions in different locations by using natural ventilation that ensures thermal comfort. We propose a ventilation design with natural ventilation from Mbaru Niang's traditional house. It was found that raised floor, verandah, and sun shading can reduce the hot temperature from solar radiation and hot wind from the sea breeze. This modern building concept can become a practical, healthy, and environmentally friendly solution for building in Flores, Indonesia. Introduction

1.Introduction

Building adaptation to climate change is urgent in Indonesia. High temperatures conduct high electricity consumption. It worsens added with the fallout of the COVID-19 (novel coronavirus disease 2019) pandemic [1]. In the face of today's health and environmental crises, it was clear that current building strategies are energy-efficient and healthy. Moreover, the Minister of Tourism of Indonesia was chosen Labuan Bajo, East Nusa Tenggara, Flores, to become one of the top tourism destinations in Indonesia [2]. Labuan Bajo is surrounded by a small island and coastal scenery (**Figure. 1**). Climate change is projected to increase sea-level rise and impacting coastal societies [3]. Coastal adaptation to climate change is a priority. In response, the Indonesian government has increasingly made concerted efforts to

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Fig. 1. Labuan Bajo, East Nusa Tenggara, Flores, one of top tourist destination in Indonesia. The island is surrounded by small island and coastal scenery [4].

reduce energy consumption by launching a target to achieve universal electrification by 2025 [5]. The primary mechanism used to save energy only focused on cooling. In the face of today's health issue, ventilation for air exchange must be included in a cooling system [6]. Understanding the local climate is mandatory to achieve a healthy and efficient energy performance, especially the ventilation design. However, the current energy policy for mainly building focused on building that located on Java Island. The general tendency is that the building codes are copied from Java Island climate, not Flores's local condition. Unlike in Java Island, Labuan Bajo is built on uneven limestone topography with highly seasonal rainfall in town averages 1200 mm/year and a temperature average of 27°C [7]. The clear guidelines for local climate design are necessary to create healthy and efficient buildings, especially in Labuan Bajo, since this region will be developing soon as a top tourism destination.

Vernacular buildings have always made use of local materials and adapt to the local climate. The understanding of vernacular building can be a guide to design a healthy and efficient building. Concerning tourism, analysis of local materials, culture, and weather can reduce the building cost and preserved local value to become the area's identity. Mbaru Niang, one of vernacular house located in Wae Rebo village, Labuan Bajo, East Nusa Tenggara (**Fig. 2**). The unique shape and thermal performance of Mbaru Niang show significantly better thermal comfort compared to other local buildings [8]. Moreover, duplicate the shape could preserve the local identity.

Fig. 2. Mbaru Niang houses of Wae Rebo village, Labuan Bajo, East Nusa Tenggara Indonesia [9].

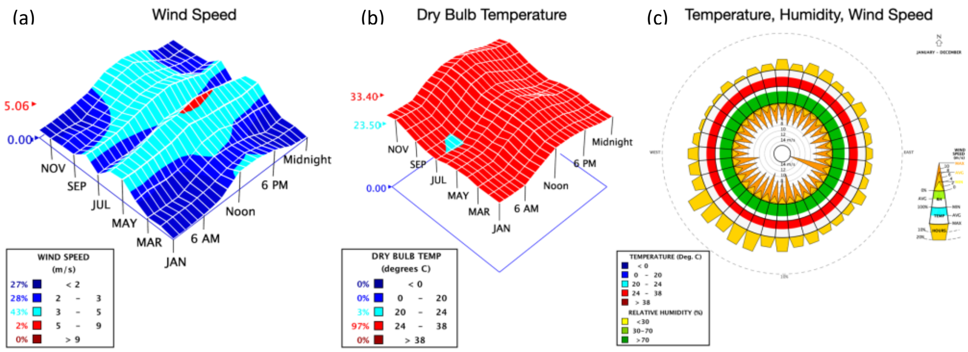

Fig. 3. Manggarai Barat's weather data: wind speed, dry bulb temperature, humidity, and wind direction.

As people spend more of their lives within buildings because of this pandemic, the environmental comfort and efficiency of electricity are strongly related to the productivity of its occupants. This research aims to find the best strategy to design a healthy and efficient building in Labuan Bajo, Indonesia, from Mbaru Niang. In the future, this strategy can be used as a designer and government guidelines. This paper was organized in a different section to evaluate how to implement a vernacular building strategy in a modern building. Section 1 discussed this research background. Mbaru Niang's design and performances are analyzed in section 2. Next, section 3 shows the sample of building design for the tourism center and simulates the natural ventilation. Moreover last, section 4 shows the conclusion and recommendation. These design guidelines have provided a simple and easy strategy to improve the health and efficiency of our environment.

2.Mbaru Niang design and local weather analysis

Mbaru Niang located in Wae Rebo village, Mount Pocoroko, Manggarai Regency, Flores, East Nusa Tenggara, Indonesia. It is a remote mountain village within the dense rainforest mountain of Flores, Indonesia [10]. This form is common in indigenous settlements in the Manggarai Flores area. Mbaru Niang is one of the unique vernacular architectures in Indonesia. This shaped house is almost similar to the Honai in Papua Island, Indonesia [11].

2.1.Weather Analysis

Manggarai Barat Regency is located between 080 14' – 090 00' South Latitude dan 1190 21'–1200 20' East Longitude [12]. The total area of Manggarai Barat is approximately 3 141,47 sq. km, which consists of Flores Island And some other large islands such as the islands of Komodo, Rinca, Longos, and other small islands. It has two seasons, dry season and rainy season. Climate Consultant software [13] was used as a simulator tool for more detailed local weather data analysis. This software reads the local climate data in EPW (Energy Plus Weather) format and displays dozens of different graphic charts of various weather characteristics. Understanding local climate data was the first important step to decided future design strategies. Additionally, the weather data were collected via the Meteorology, Climatology, and Geophysical Agency (BMKG) [7].

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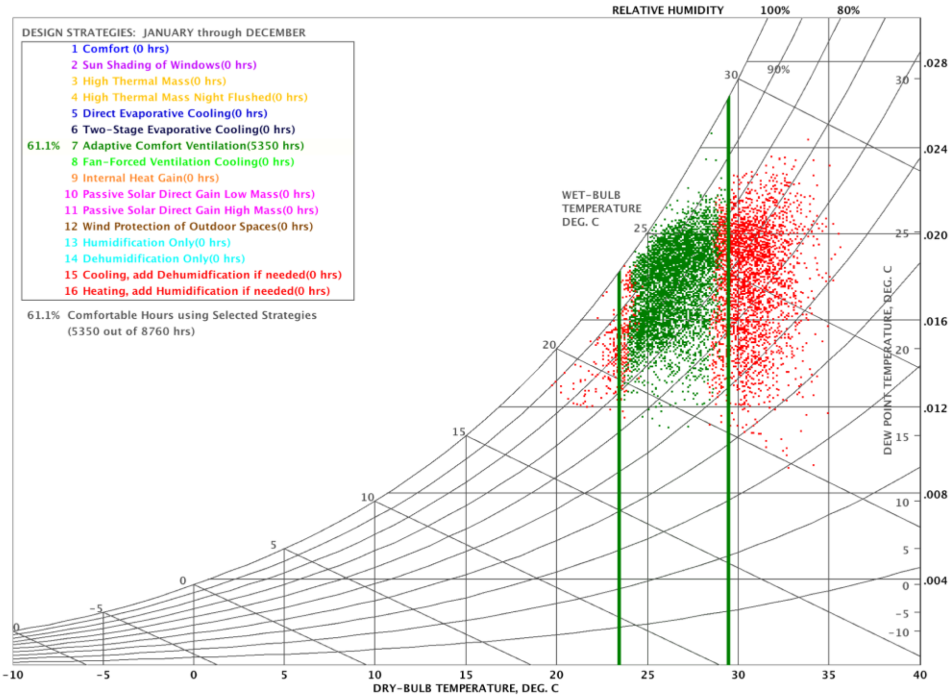

Fig. 4. Psychrometric chart of Manggarai Barat, Flores Island, Indonesia.

Manggarai Barat's weather data is shown in **Figure. 3.** Wind speed (**Figure. 3a**) in this area is relatively high, from January to May around 2-3 m/s. The other months are 3-5 m/s. This wind speed is higher if compared with the average wind speed in Java Island [14]. Dry bulb temperature is shown in Fig.4b. This chart is the average for each month in a year. Dry bulb temperature is relatively stable throughout each month. The dry-bulb temperature (**Figure. 3b**) in Manggarai Barat is dominated by hot and humid every month. The wind rose in **Figure. 3c**, describing the predominant direction and frequency, and velocity wind in Manggarai Barat. Red shade displays the temperature range between 24-38 °C. Light green shade displays relative humidity above 70%. The wind direction dominantly comes from Australia (south).

Climate consultants also provide an adaptive comfort strategy, as shown in **Figure. 4** The design strategies were pictured on the psychrometric chart. The psychrometric chart is a widely-used visualization for understanding the relationship between supply air and relative humidity [15]. Every hour in the climate data file is shown as a dot on this chart. The x-axis represents the dry-bulb temperature, and the y-axis shows the fresh air humidity. The adaptive comfort strategies in this diagram are used to evaluate thermal comfort in a commercial building located in Manggarai Barat. **Figure. 4** shown that the only proposed strategy for Manggarai Barat adaptive comfort through ventilation (61.1%). Some strategies that can be used such as:

- Reduce the air conditioner, and increase natural ventilation from the window,
- Cover the window with shading to minimize the solar glare and radiation,
- Locate opening (door or window) facing upwind. In this case, the wide opening will be located on West and South's side of the building (the strongest wind direction come from the south),

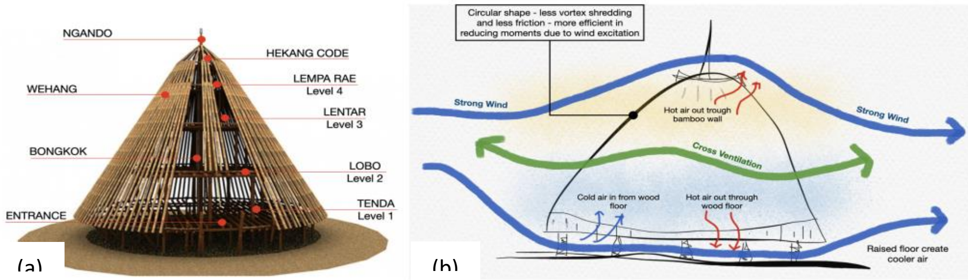

Fig. 5. (a) 3D render of Mbaru Niang and each component's name [10,16], (b) Air flow and natural ventilation in Mbaru Niang.

- Use open-plan interior to promote natural cross ventilation,
- Design the high ceilings, window shading, and verandah to increase cross-ventilation,
- Provide enough glazing in the South building area to balance daylighting,
- Use plant as one of building element to minimize the heat gain,
- Maximize natural ventilation from raising the floor,
- Shading for west-facing glazing to reduce heat gain,

Whenever possible, passive strategies will be proposed to the future design. The use of natural ventilation while maintaining thermal comfort is essential, especially during the current pandemic. These strategies will be applied to help reduce the use of energy-consuming and healthy buildings.

2.2.Mbaru Niang design analysis

As mentions in some references [8-10,16,17], Mbaru Niang's basic shape is a cone and has five floors with a height of about 15 meters [17] (**Figure. 5a**). Vernacular building usually has adapted well to the local climate. This aerodynamic shape can protect the occupant from strong wind (**Figure. 5b**). The cone shape caused smaller separation zones and narrower wakes than a square shape [18]. This shape is more efficient in reducing moments due to wind excitation.

One of the strengths of the vernacular building is that it uses local materials and understands the local condition. The buildings are assembled with natural materials. Reeds were used as the primary material for the roof and wall. The reed is one of the fast-growing plants. Wood is the primary material for the floor and structure. Bamboo is rarely used for envelopes, but it is used for the main structure in the middle. Large roofs bring insulation benefits to prevent intense solar radiation and ventilated attic spaces. The roof shading device in Mbaru Niang also prevents heavy rain. However, this large structure minimizes daylighting. One of the vital characteristics of an Indonesian house is the raised floor. The raised floors have allowed the house to be ventilated through a wood floor. It also offsets the radiated heat gain from the hot-dry ground outside (**Figure.5b**).

The basic concept of Mbaru Niang is an open plan and form of a circular pattern (**Figure. 6**). The house is arranged into a radial configuration divided into either individual rooms or separated portions. The arrangement and orientation of Mbaru Niang is an open U shape facing the front yard. An open plan is better than a semi-open and ordinary plan in reducing energy consumption and giving the occupants more freedom to design based on their daily activities [20]. The open plan also effectively reduces energy consumption [20].

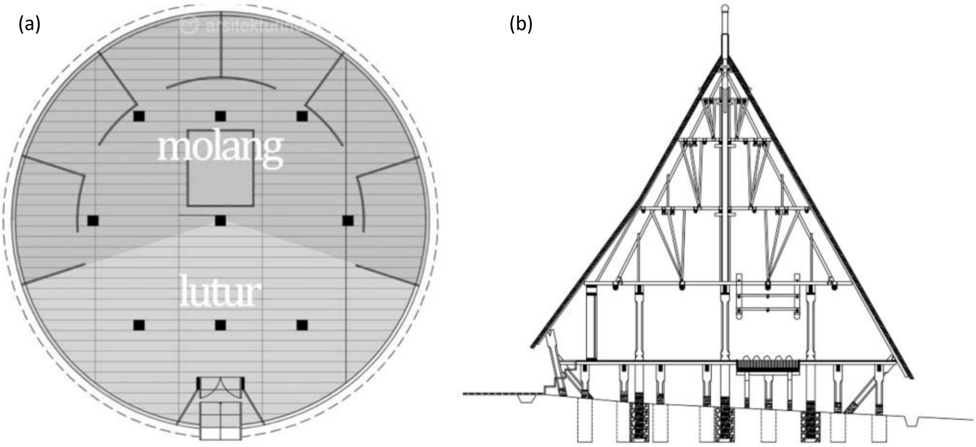

Fig. 6. (a) Spatial organization and (b) Section of Mbaru Niang [19].

This chapter presents Mbaru Niang passive design technique. A cone-shaped building, extensive shading, natural ventilation, and raised floor in Mbaru Niang might have optimal thermal comfort performance. This building adaptation is almost similar to the previous suggestion from Climate Consultant weather analysis. Combine whether data strategies and traditional concepts could achieve thermal comfort in a modern building in Labuan Bajo.

3.The architectural model

The architectural model adopted from Mbaru Niang is shown in **Figure. 7** This building located in Labuan Bajo and the purpose of this building become a tourism center. It not only the center of culture but also become a landmark of Labuan Bajo. The site is located at the top of the hill and can see the beautiful scenery (360 degrees view) in Labuan Bajo. The tourism center nearby the sea experiences high humidity and high solar radiation which make the thermal condition uncomfortable during summer. The orientation is based on the state of wind direction. The main principle used in this building is to reduce heat and humidity by using natural ventilation.

As shown in **Figure. 7**, the tourism center building contains five floors, similar to Mbaru Niang. The first floor is used as an exhibition space and convention center. Next level space concentrated as a museum and culture gallery. Visitors can enjoy Labuan Bajo's beautiful view on the third floor. The top floor is used only for roof and ventilation. To strengthen local culture, the raised floor was chosen.

The buildings were designed to achieve cross-ventilation through void (**Figure. 8a**), verandah (**Figure. 8b**), and ventilation grid (**Figure.8c**). This building is designed to maximize the daylight through void and skylight (**Figure. 8a**). The tourism center also had large overhangs around the third floor, which will reduce the sunlight entering inside the building. The types of sunshades are shown in **Figure. 8b**. In this paper, two types of sunshades (horizontal and vertical grid) are selected for optimization.

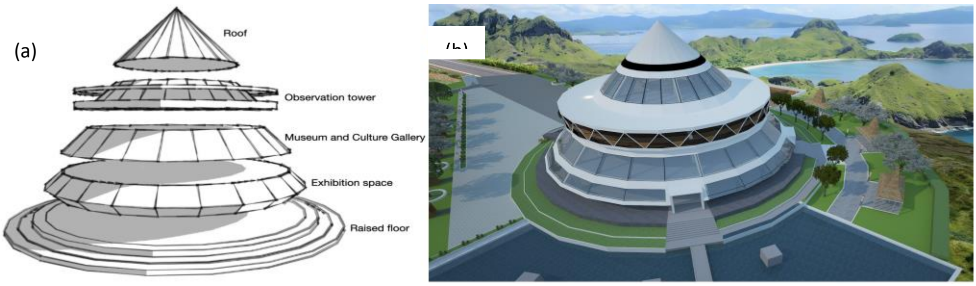

Fig. 7. (a) Concept design of modern Tourism center based on Mbaru Niang's concept; (b) Final rendering of Tourism Center in Labuan Bajo.

4.Natural ventilation analysis using CFD

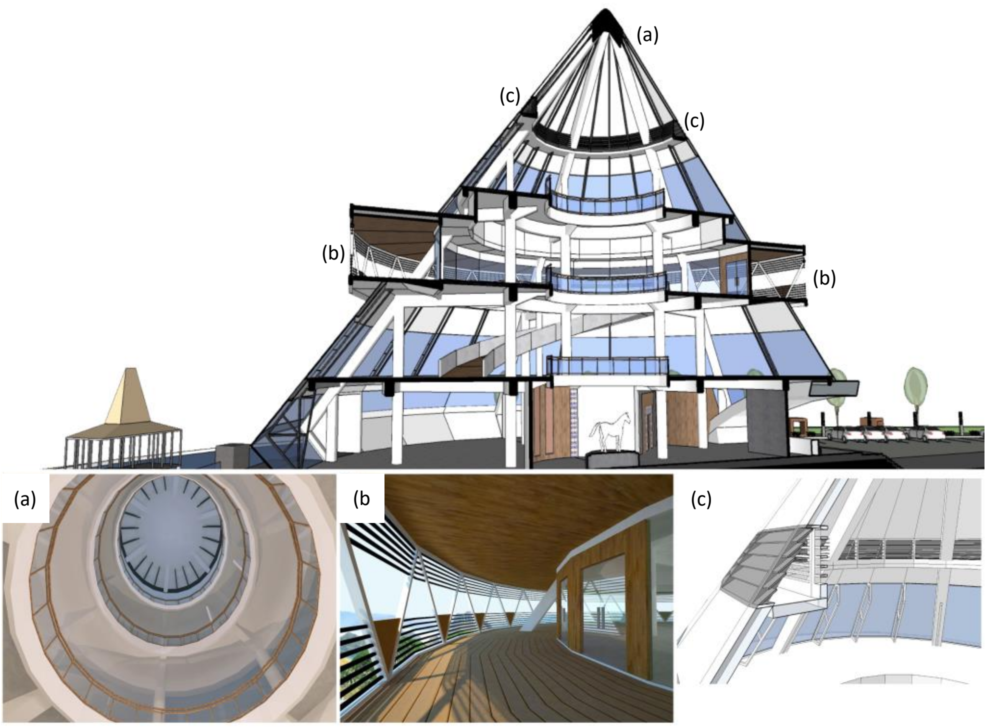

Fig. 8. Adapt strategies used for tourism center in Labuan Bajo: (a) void from first floor to top floor to air circulation and skylight to maximize the daylight; (b) shading and verandah for reduce the heat transfer; (c) ventilation grid for heat exchange.

https://doi.org/10.1051/e3sconf/202131704017

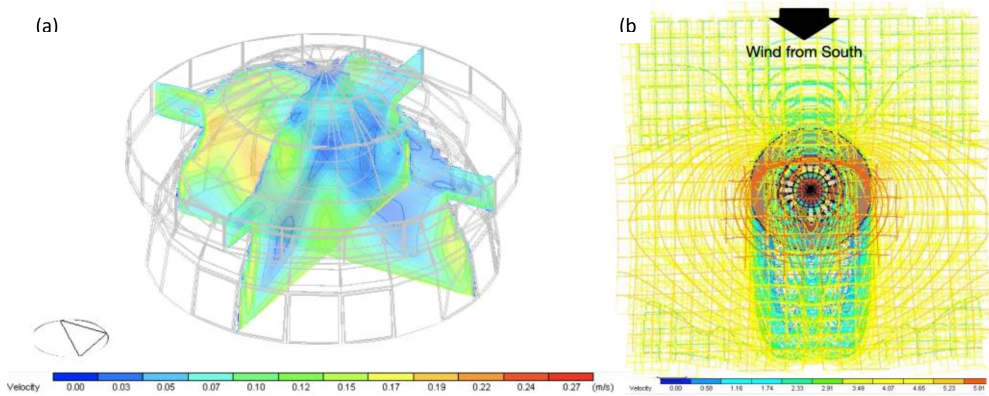

Fig. 9. CFD analysis result in Labuan Bajo tourism center. (a) Internal simulation result; (b) External simulation result.

To understand the natural ventilation performance, Design Builder Computational Fluid Dynamics (CFD) was used to analyze the tourism center in Labuan Bajo. Computational fluid dynamics (CFD) simulations provide a comprehensive analysis of the internal flow pattern and can be used as a guideline in the preliminary design concept. The inside and outside air flow of the building were simulated in Design Builder CFD. This research will inform the design of the naturally ventilated building that maintains thermal comfort. The COVID-19 crisis has exposed the importance of airflow through cross ventilation.

As shown in **Figure. 9**, wind direction comes from the South. The standard k–ε model was considered to simulate the turbulence effects. k-ε model is one of the most widely used and tested of all turbulence models, belonging to the so-called RANS (Reynolds Averaged Navier-Stokes) family of models [21]. **Figure. 9a** shows the simulation results for internal CFD analysis. Two different slide contours are shown in Figure 9a. The first slice shows wind conditions in the South-North section. The second slice shows wind conditions in the West-East section. In **Figure. 9a**, air movement can be observed come from opening on the first floor and passing in the void area. The wind velocity increases on the first and third floor (0.15-0.17 m/s) then decreases to the void area (0m/s). Wind velocity mostly comes from a ventilation grid on the top floor and a nearby glass window on the first floor. Heat flow from inside the building moves to the ceiling and then moves outside through the open ventilation on the roof. The raised floor is also effective in catching more wind than the landed floor. Combining the raised floor, large verandah, void, and ventilation grid on the ceiling can significantly increase the air movement inside the tourism center.

Figure. 9b shows the CFD results for the plan view's slices illustrate the velocity contour. As mentioned in previous reviews, the wind flows pass through the circular shape and create less vortex shredding and less friction. This shape proves more efficient in reducing moments due to wind excitation in coastal and hill areas.

5.Conclusion

The importance of cross ventilation because of the COVID-19 pandemic for the current building designed is mandatory. This primary purpose is to provide air circulation and reduce energy consumption. Natural ventilation is the easiest method to achieving fresh air. Both energy efficiency and thermal comfort can be achieved through this strategy.

Mbaru Niang, one of the iconic vernacular houses in east Indonesia, was investigated and analyzed. This traditional building performed well with Flores Island's local climate. Climate adaptation design is necessary to achieve user comfort and efficient energy, especially in hot, dry climate conditions like a tropical island in Flores. Applied these traditional strategies (large roof, sun shading, raised floor, cone-round shape) to modern buildings showed can increase the natural ventilation.

The modern design was proposed to become Labuan Bajo tourism center. This building is located on the top of a hill in Labuan Bajo, Flores, Indonesia. Local climate dominated with strong wind, hot, and dry climate. Raised floor, large window opening, large verandah, shading, void, and ventilation grid was used to increase the wind circulation inside the building. The CFD simulation results have demonstrated that these strategies increased the potential for natural ventilation in a tropical climate. Raised floor contributes to creating better air circulation through heat transfer from the entrance to the void then out through the ventilation grin on the top floor. Simulations results showed that higher velocity dominated in this building—lower velocity located in void area.

This paper raised the awareness of the importance of traditional strategies, such as the raised floor, ventilation grid, and shading design, which helped open possibilities for improving natural ventilation performance. This will bring new opportunities for using this old passive cooling system in today's world. It can also be used as a design guideline for designers and government before designing the building outside Java Island. This traditional and straightforward passive design was easier to apply and promote local identity.

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