Conference Paper

Why Is the Attic Ventilation Disappearing from the Current Urban Houses in the Humid Tropics?

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Abstract

The construction of a townhouse built today no longer has roof vents, compared to colonial buildings as well as traditional architecture scattered in humid tropics. In Indonesia, many buildings are made with a zinc roof, even in North Sulawesi province 92 percent of zinc roofed buildings or metal aluminum. This article has two purposes, the first is to assess the benefits of attic ventilation, especially for zinc roofed buildings and the second is to find out why the ventilation loft is no longer used to present buildings. Research by building two same test cells where one cell has roof vents, and the other cell does not. The test cell with ventilated roofs has the advantage that the interior temperatures are lower on average by 1.2 °C than those in a cell without ventilation. Almost all buildings today have a modern and minimalist style where the shape and pattern are delicate and do not allow for roof ventilation; such structures cannot form adequate attic spaces. Based on observation and evaluation, this is the leading cause of the disappearing of attic ventilation.
Another thing was caused by efforts to reduce the selling price of a house with consideration of people's purchasing power. Ignorance from building owners and developers on the benefits of attic ventilation to reduce room temperature and lighting is one of the factors found in this study; even this problem is made worse by architects who often ignore these benefits in their designs. Comprehensive knowledge is needed for the general public and also for architects for the use of roof ventilation which in turn is an effort to achieve thermal comfort and energy savings in the domestic sector.

Keywords: attic ventilation, urban houses, modern and minimalist style, thermal comfort, energy savings, humid tropical regions

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Received: 24 May 2019
Accepted: 25 July 2019
Published: 4 August 2019

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ISTEcS 2019 Conference Committee.

1. Introduction

The roof is an essential component of the house and building. This component becomes a barrier for rainwater and also the most exposed to the sun. This condition causes the roof to be hotter than other parts or components of a building. Heat absorbed by the roof layer will be transmitted to the room beneath it or reflected the surrounding environment. The amount of heat through conduction and convection depends on the

How to cite this article: Jefrey I. Kindangen, Octavianus H.A. Rogi, and Verry Lahamendu, (2019), "Why Is the Attic Ventilation Disappearing from the Current Urban Houses in the Humid Tropics?" in *Equity, Equality, And Justice In Urban Housing Development*, KnE Social Sciences, pages 394–407. DOI 10.18502/kss.v3i21.4983

type of roofing material [1]. To prevent heat directly into the room below it is often used the ceiling and will form an intermediate space called the attic.

According to the observation that the current housing construction began no longer heed the use of attic ventilation, in contrast to what is encountered in traditional Indonesian architecture and also in Dutch colonial buildings. Many buildings have roofed with zinc or aluminum that quickly absorbs heat and also easily release heat. The question is whether the roof vents have a function or are no longer useful so left out. If there is any benefit then how much does it affect to reduce the spread of heat to the room beneath it?

Climatic conditions in Indonesia which are a humid tropical climate has always been a significant issue of thermal discomfort. In a hot environment and coupled with high humidity, a person will feel warm and will sweat. If there is no evaporation from the skin surface, then someone will feel uncomfortable. In such conditions, it takes airflow that psychologically and physiologically can evaporate the sweat on the skin and give the impression of more relaxed, of course, the main thing is how can lower the temperature of the room. Thus reducing the temperature of the room in a way and the right strategy can create a comfortable space.

2. The Traditional Indonesian Architectures

Concerning climate suitability, Givoni [2] stated that there is a very close relationship between humans and climate and vice versa; even Olgyay [3] indicated that environment determines architectural features in an area; including the use of available materials and compatible with the local climate. Architecture always is seen as the culmination of long-term interactions between humans and nature. We can find that building construction in extreme environments is very close while in neutral climates the structure is characterized lightly and minimizes complexity in architectural design. The architecture in moderate climates lies between these two extremes. They tend to be more selective in handling the local environment. The architecture in temperate and hot climates has an open transitional space while the architecture in temperate regions has a transitional and transparent space. Potvin, as cited by [4], showed this trend where the complexity of architectural transition is a function of the type of climate, as described in Figure 1.

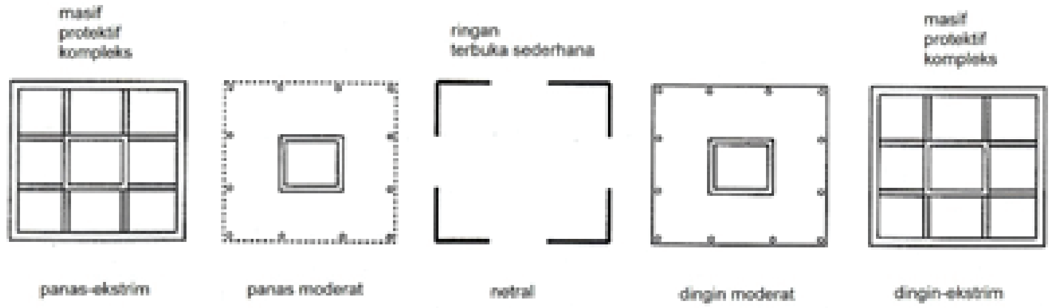


Figure 1: The complexity of the architectural transition functions of the type of climate.

2.1. Typical construction in humid tropical climates

Buildings in humid or dry tropical climates require an appropriate architectural design. For a humid tropical climate, it is light and open construction, while for dry tropical climates more in line with closed architecture and high thermal mass. The porosity of the exterior wall determines the degree of openness of construction, i.e. the ratio between the window or door or ventilation hole against the corresponding wall area. While light assembly is characterized by the use of light materials such as bamboo, wood, tree trunks and so forth [5], as well as other modern materials can also be used in conditions that take into account the climate context. In humid tropical climates, low temperatures throughout the night are very weak to allow for cooling of structures with night vents. In the context of passive cooling, without the use of an active system, must consider the protected construction from direct sunlight and use permanent ventilation to avoid overheating in the building.

2.2. Appropriate architectural elements in a humid tropical climate

Architectural elements that are suitable for humid tropical climates and often encountered in vernacular architecture used to overcome climate barriers and use local materials are as follows:

2.2.1. House on stilts

Almost all traditional Indonesian architecture is built on stilts; the floor is lifted a few meters above the ground. Although initially, the aim is to protect from wild animals and enemies; this situation has the advantage of avoiding buildings from soil moisture and exposing them to stronger winds. However, financial limitations limit this type of construction.

2.2.2. Sun protection and attic

Home construction is made with a wide-rise roof to protect large openings from rain and also from direct sunlight. Between the roof cover and the ventilated attic room allows heat evacuation due to absorption of solar heat on the roof surface. Attic ventilation is also part of the attic lighting system that allows natural light to penetrate the attic space, as presented in Figure. 2. In modern architecture and for public buildings, sun protectors define the definition of facade architecture.

Figure 2: Traditional architectures in a humid tropical climate. (Source: [18-21])

One of the essential characteristics of traditional architecture is to have attic ventilation. Several researchers have studied the benefits of attic ventilation. The US Department of Housing and Urban Development [6] investigated design strategies for roof ventilation in fabrication houses; and recommended the benefits of roof ventilation for several reasons: humidity control, energy conservation, the durability of asphalt roofs, and avoiding ice freezing. The research team recommended designing different roof ventilation systems according to the climatic conditions in each US state region that are very different from each other. This study showed that the design of roof ventilation in houses in hot and humid climates was more beneficial than in homes that were not ventilated. However, this research did not describe the actual environment in Indonesia or Manado, and also the roofing material was a relevant material used here. For traditional architecture, the roof material commonly used is material that comes from nature, while in many buildings today it uses zinc roofing material. There is 92 percent of houses and public buildings using zinc roofing in the province of North Sulawesi, according to data provided by the North Sulawesi Central Bureau of Statistics [7].

Research by Beal et al. [8] carried out by comparing two types of roofing material that are ventilated tile roof compared to black shingle roof; it obtained a reduction of 48% heat flux for ventilated tile. It seems that the thermal mass of the pipes and ventilation between tiles is a dominant phenomenon in reducing the cooling load on the roof like that. The use of roof ventilation was also suggested by Rose [9] who emphasized the importance of research for the shingle roof industry and began to be associated with sound installations and recommended the use of roof ventilation in the mid-1980s to control the humidity in the space between the roof and the ceiling.

The US Department of Energy for Energy Efficiency and Renewable Energy [10] has issued guidelines for creating more airtight ventilation with insulation. But this cannot be applied in a humid tropical climate and is more suitable for cold climates.

Quarles et al. [11] suggested that the roof ventilation design was needed for humidity control and also for indoor heat control. The same thing was done by Purswell et al. [12], they researched livestock pens and concluded that with roof ventilation, humidity could be reduced compared to houses that have traditional ventilation systems on one side of the wall.

3. The Dutch Colonial Architecture in Humid Tropics

Sumalyo [13] identified Dutch colonial influence on urban development and architecture in the city of Makassar. Dutch colonial settlements in Makassar are similar to other places in Indonesia which, starting from inside the fortress (Intramuros). Such a living arrangement is an expression of the human instinct to protect one's life from external threats. Fort Rotterdam shows the influence of European culture; the architecture resembles medieval architecture.

Dutch colonial architecture in Indonesia is an example of a unique blend of west and east in tropical and traditional countries. Dutch people are susceptible to tropical climate. In Java and also in other islands in Indonesia, many Dutch colonial architectures were outstanding in natural ventilation and lighting as a mixture of early European modernism and traditional architectural influences, as shown in Fig. 3 (a-f).

a. 'Agriculture school for native teachers' Yogyakarta

b. Fatahilah Museum Jakarta

c. Lawang Sewu, Semarang

d. Fort Rotterdam, Makassar

e. Merdeka Building, Bandung

f. de Vries Building, Jl. Asia Afrika Bandung

Figure 3: Some examples of Dutch Colonial buildings in Jakarta, Yogyakarta, Semarang, Makassar and Bandung. (Source: [22 – 29])

Ardiyanto et al. [14] explained that the shape and layout of the traditional architecture were adopted to the modern colonial architecture in various types of building. The form of colonial architecture is also compromised with the typical architecture of Indonesia. Thus it has its own identity and orientation. Some of the features of humid tropical architecture applied in colonial buildings are the wide opening, ceiling ventilation, and pitch roof, the existence of porch or gallery, and high-density walls (heavyweight structure) are some of the specific characteristics of colonial architecture for maximizing the natural ventilation during the day.

Ardiyanto [14] explained that in terms of the perception of the effects of wind, sun, and rainfall, construction elements were made to overcome the problems of wind motion stability and rain protection, such as sloping roofs to anticipate rain, corridors around the building to isolate heat, connect buildings and function as dark areas, high ceilings with grids, ventilation systems, and windows that are opened widely and almost cover the walls of buildings. One example is the Mayor's office building in Surabaya has a long-shaped building with corridors in front of and behind the building, as shown in Fig. 4.

Figure 4: Surabaya's Town Hall. (Source: [30])

The leveled roof with the hole is to make the room cool so that it can reduce the heat transferred through the ceiling into the room. As illustrated in Fig. 3, on the roof there is always a dormer associated with a place for lighting or ventilation; or also as a roof vent only. There is ample space in the middle which serves as the room to welcome guests where the air is circulated through the cross ventilation. The office building has a full row of windows to allow smooth air circulation inside the room.

Surabaya Town Hall Building has an elongated shape, which extends east-west. It aims to minimize the part of the exposed wall of the sun's heat which will affect the reduction of temperature in the building space. Also, the north-south direction is also useful to maximize the occurrence of air circulation cross (cross ventilation). The problem of air and natural lighting systems in space is solved with a "double-leveled" roof shape with ventilation holes between the two roof slits. This hole is the entrance of light and air into the room. Almost all buildings, especially large ones, have hallways that surround the place on the outside. This multifunctional section serves as a connector and sun thermal protection; as does a large roof with a fine pitch that sometimes consists of two layers with a gap to circulate the hot air. The rooms with high ceilings are also one of the strategies to prevent heat in the place. Attempts to obtain light and airflow in the attic used dormers on the roof, a common form is shown in Fig. 5, which is often used in Dutch colonial buildings. Dormers are windows or small roofed structures protruding from the sloping roof. They are usually used to add additional headroom or light to the slanted attic room or the attic conversion.

What is displayed from the average Dutch colonial building almost all uses attic ventilation as an effort to create more adaptive room conditions with humid tropical

Figure 5: Types of dormer generally used in Dutch colonial buildings. (Source: [30])

environments. In Dutch colonial buildings, the function of attic vents to evacuate hot air should not be trapped inside as well as part of natural lighting in the attic room.

4. Urban Houses Today

Almost all buildings are built today have a modern and minimalist style where the shape and pattern are delicate and do not allow for roof ventilation; these buildings cannot form adequate attic spaces. Buildings have no longer use roof ventilation because of considerations of lowering house prices per unit, according to people's purchasing power. But there is also to seek maximum profit by building houses as they are, but not comfortable to occupy, as shown in Fig. 6. The ignorance of the community causes another thing, both the building owners and the developers of the benefits of attic ventilation to reduce the room temperature; even this problem is exacerbated by architects who more often ignore this benefit. For houses that are built with comfort awareness and also as standards that are passed down from generation to generation will adhere to using attic ventilation, as shown by two houses at the bottom of Figure 6.

When the roof was designed, a lot of thought went into the ventilation system. Most roof ventilation systems are wind-driven and non-powered. To effectively take the high volume of air movement needed to ventilate the roof properly, a design has to incorporate a balance between intake and exhaust vents. In general, the net-free area of intake venting should be equal to or greater than the net-free area of exhaust venting. Net-free area is the total unobstructed area through which air can enter or exit a vent, measured in square meters.

In some instances where construction and layout are not possible using a roof vent is naturally recommended using a ventilator turbine on the roof, as suggested by Ismail, M. et al. [15], where the use of turbine ventilators on the roof has penetrated all types of buildings and is used due to climatic conditions that do not allow using natural roof vents. However, this use requires energy costs and can only be used in urgent situations.

Figure 6: Type of house built in the present. (Source: [32-34])

Ahmed S. et al. [16] researched to investigate the effectiveness of the ventilation system to achieve thermal comfort in humid tropical climates. This system consists of a solar-powered fan for attic ventilation, in other words almost similar to previous researchers using ventilators. As a result, the temperature in the dwelling space can be reduced. Hot air trapped during the day becomes a significant source of heat, the system is potentially used in humid tropical climates. Again of all current research emphasizes the use of turbine ventilators and has not investigated the roof ventilation system naturally.

5. Quantify the Benefits of Attic Vents

According to ISO 7730 [17] that Thermal Comfort is "that condition of mind which expresses satisfaction with the thermal environment." This definition of thermal comfort needs to be quantified considering that the state of mind is very abstract. Furthermore, to simplify the explanation, it is stated that the thermal environment is not only the temperature as the only main parameter, but the role of other metrics is crucial. Quantitatively, thermal comfort is influenced by two main components namely human components in the form of activity and clothing while external factors such as temperature, relative humidity, air pressure, and airflow velocity. For that in this study required measurement of external factors as the basis of the discussion.

Two similar test cells are built with a length of 1.00 m, a width of 1.00 m and a height of 1.85 m. The walls are made of plywood, and the roof is made of corrugated galvanized zinc with a surface area of 2.60 m2. The roof tilted in one direction only. This test cell has two 25 × 50 cm sized windows and window sill lays 70 cm from the ground, located on the right and left sides (North and South) to avoid direct sunlight that can penetrate through windows. Test cells are placed outside so that they can be exposed to direct sunlight as effectively as possible during the morning - afternoon. The test cells consist of two models in which one model has not installed roof vents, and other models are installed roof vents. The measurements use RC4-HC dataloggers that measure air temperature and relative humidity. Each test cell uses 2 RC4-HC dataloggers with proper placement, as illustrated in Fig. 7.

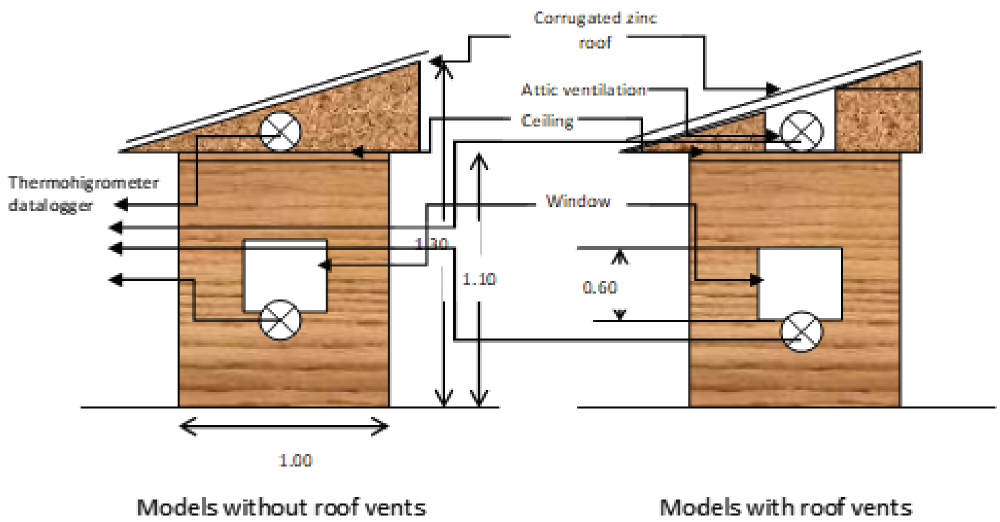
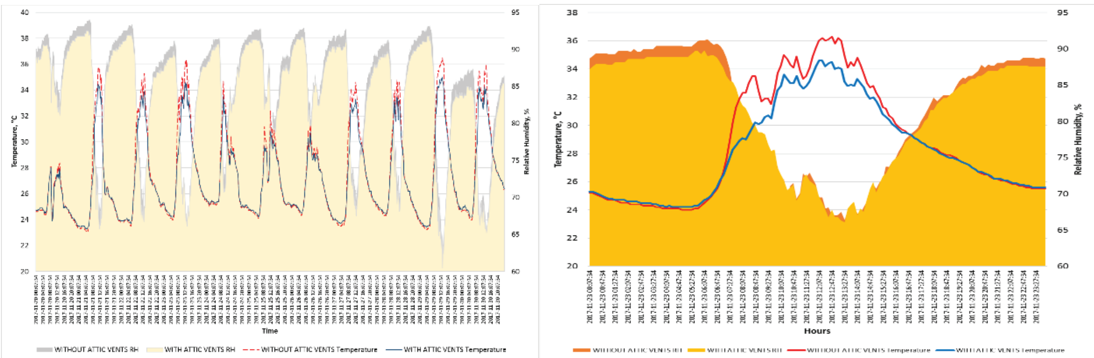


Figure 7: Modeling of two test cells. (Source: own author's work)

The measurement results show that the use of roofing vents provides an advantage where indoor temperatures of cells that have roof vents are always lower than the temperature on cells without roof vents, as shown in Fig. 8a. The indoor temperature under a ventilated roof is still lower than the room temperature under an unventilated roof, and the difference may be as much as 2.1 °C or an average of 1.2 °C, especially during the day. At night the temperature of both cells is always the same or different not significantly. Due to the cooling that occurs at night does not require another strategy.

The effects of heat during the day are more sensitive and capable and can cause significant warming during the day. It has been proven that daytime passive cooling strategies such as cross ventilation and attic ventilation can provide considerable benefits.

In detail, on a single day, the temperature curve in the two cells is shown in Fig. 8 (b) where from 7 a.m. to 4 p.m., the use of roof vents shows excellent benefit in lowering the indoor air temperature.



(a) (b)

Figure 8: Results of measurements on the test cells (a,b). (Source: own author's work)

6. Conclusions

The use of attic ventilation in traditional Indonesian architectures is a wise consideration in adapting to a humid tropical climate environment; especially in terms of avoiding the hot trap in the attic. This consideration was raised again in Dutch colonial buildings scattered throughout Indonesia; which in principle is friendly to the humid tropical environment. On the roof are made holes for ventilation naturally, that is good to drain the air from and into the room beneath it or drain into the attic. It can be seen from the application of several types of the dormer on the roof of the building.

Most buildings built in the present are no longer using roof vents for several reasons, including the architectural form of the building is too minimalist and cannot be applied to the roof vents. Consideration to get the low price of construction that can be reached by the society especially for the middle and lower economic society also has forced the presence of buildings that do not consider the comfort aspect especially the application of attic ventilation. Another thing that is the reason is the desire to seek as much profit as possible by the developer without considering the comfort of the occupants, but only the beauty of the facade only. The unfortunate thing is the ignorance of the architects themselves and also the public against the benefits of using the attic ventilation to get cooler room temperature.

The measurement results are by building two test cells, where one cell uses attic ventilation and the other does not show that the advantage of using roof ventilation is that the indoor air temperature below is always lower than not ventilated, averaging 1.2 °C. More strategic interests in terms of meeting the thermal comfort of occupants and consideration of reducing the use of equipment that requires energy or electricity is needed to provide a more in-depth understanding to the community in considering the use of attic ventilation. Specific rules or building standards are needed.

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