Modern Tropical House: Elevating Traditional Tropical House on Thermal Building Performance Due To Environmental Issue

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Abstract. Traditional tropical architecture is built using local materials by applying passive design strategies to fix heat problems so the occupants feel comfortable and protected. Over the years, climate change causes rising temperatures and modernization causes the aesthetic element to become important in urban areas. Modern Tropical is a design trend that is now developing after the era of modern minimalist trends which not only tried to solve the heat problem but also the aesthetic problems of tropical architecture. This research aims to evaluate thermal performance in the modern tropical-style house in response to climate change and also how they adapt and modify traditional tropical architectural elements to improve their thermal performance by using the simulation method with the assistance of ECOTECT software. The results showed that houses that adapted and modified elements of traditional modern tropical homes up to 95%, showed better thermal performance. That house can provide thermal comfort for 7 hours and only 31% of percent dissatisfaction. Elements of roofs, openings, sun shading, and local material coatings on traditional architecture are elements that can be adapted and modified in modern architecture. So, tropical architecture no longer looks old fashioned but more stylish while responding to environmental issues.

1. Introduction

1.1. Tropical Architecture and modernism

Traditional houses are built using natural resources that are eco-friendly and designed using natural strategies namely passive designs that adjust the local climate so it can provide comfort to occupants without adding any cooling technology [1]. But over time and the development of global issues regarding the environment, traditional houses have changed and adapted to existing conditions. Climate change, which is the effect of global warming and modernization, is the cause of changes in some aspects of traditional houses. Global warming causes heat problems that have been tried to be dealt naturally with passive design by traditional houses are now no longer resolved so that the need arises for additional equipment to reduce the heat in buildings, namely air conditioning technology. Besides, the modernization that influences people's lifestyle also gives its own changes in terms of functions and aesthetics that affect building design, especially for people living in urban areas. So that a new style emerges that tries to combine the needs of urban communities that are practical, dynamic, and prioritize aesthetics but also provide a good response to the problems of heat caused by global warming and still maintain the identity of the outline design of tropical architecture. As stated by
Kamarudin [2]. As time progresses, the latest architecture adopted and developed from traditional architecture became more comprehensive and also aesthetically in shape.

The biggest issue, which is climate change, has been widely discussed in various sectors, including the building sector and debated by various countries in the world including Indonesia as a humid tropical climate. It is believed that the building sector will be affected by the phenomenon of future climate change about the thermal building performance, energy needs, and also the comfort of the occupants [3]. This is because the tropical climate can have high temperatures as one of the extraordinary effects and other extreme things such as sun exposure, relative humidity, rainfall, and wind velocity [4], especially now there has been a phenomenon of climate change. Climate change causes the tropics to experience a rise in temperature and according to [5], the plan and construction stages have paid little attention to the thermal performance of buildings lately. Pieter de Wilde [6] said that the building should present an intermediate layer between the outdoor and indoor environment that has a gap so can maintain the stability the indoor conditions to provide comfort to the occupants.

And the statement was affirmed that an interpretation of environmental aspect including plan and construction of the buildings is one of the requirements to providing comfort to its occupants successfully [4]. Accordingly, to decide what elements of a traditional house that has good performance in protecting its occupants from the heat that can still be maintained and has a sustainable concept, it is very important to study existing traditional houses [1].

In an all-modern era, the need for a house is not only limited to fulfilling functions as a sanctuary but also there is a need for aesthetics so the trends in building design changes from time to time. In addition to aesthetics, the modification of local culture and modern lifestyle is one of the challenges from interpreting modern definitions in tropical architecture besides the climate problems [7]. Joo-Hwa Bay and Boon-Lay Ong also state that the sustainable concept is not considered so it is rarely applied and architecture which good aesthetically that also applies the sustainable concept is failed environmentally. In other words, combining a design that is responsive to the environment, especially thermal problems with aesthetics is not easy because there is usually one that is abandoned. This is also justified by Manzano-Agugliaro [8] that function and energy are the main focus of traditional architecture while modern architecture is more focused on functions only. Through creative designs by applying building science directly in the design process and surrounded by environmental issues is the only way for architects to be able to carry out their roles [7].

1.2. Climate as design generator
The latest architecture is being developed continuously with the integration of traditional architecture specifically about natural cooling and combining local materials and modern materials for structural strength [5]. And Tropical Modern is one of them which is also a modern post style because it is a blend and refinement of the previous style. Adaptation of modern trends, in terms of design and construction that can respond to the local climate, is the definition of modern architecture at the lowest level by considering lifestyle changes that occur [7]. Heat stress in the urban area is caused by extreme heat which in turn increases energy demand due to the high need for air conditioning [7]. Therefore, modern tropical architecture tries to complete traditional tropical architecture in overcoming heat which can no longer be overcome by passive design and reducing the use of air conditioning by changing and adapting several parts. As the results of previous studies indicate that buildings using smaller openings indicate lower temperatures in buildings, which is contrary to the belief of ordinary people that wide openings are more appropriate and better applied in tropical climates [9]. And recent evaluations show that the performance of natural ventilation can increase by reducing the size of openings. Previous research also stated that roofs and roofs that were given insulation were the most effective strategies to reduce excessive heat entry [10]. Regarding the use of material, in previous studies showed that traditional architecture combined with modern material is more adaptive 80% to the limits of thermal comfort standards [5]. And about the shading elements, which are important elements in tropical architecture to dispel heat, previous research states that shading device placed on the side of the wall will be more effective than on the side of the glass window [11]. Other studies suggest that they found the application of passive design can indeed reduce thermal discomfort but cannot provide thermal comfort throughout the day and indoor temperature exceeds the standard of
thermal comfort up to 80% [12]. These points show that some elements in traditional tropical architecture can be adapted and modified to increase the thermal performance of modern buildings in a humid tropical climate for a better.

Therefore, research on modern buildings in humid tropical climates that apply the modern tropical style to elements that affect their thermal performance has never been done before. So this research was conducted to evaluate several modern tropical houses related to the thermal performance of the building to determine the response to the surrounding environment. It aims to find out the extent to which modern tropical houses adapt traditional tropical architecture because not all elements of traditional tropical homes can be immediately applied. And also which is the best thermal performance in adapting to the current climate change so that it can provide comfort to its users.

2. Method

2.1. Buildings description

The subject to be examined is a modern tropical style on the building envelope and the object is a residential house in Surabaya. In this research, what is examined is about the forming element of the envelope building as a characteristic of a style and as a form of modification of the previous traditional style and its effect on the thermal conditions in the building.

Based on the typology of the form of residential buildings in Surabaya, the type to be examined is row house. The type of residence that the building or housing unit attaches to the right or left side of the building. The type of housing chosen is middle to upper housing which has the potential for a modern tropical style because financially the owner has enough funds to renovate or build a house following the existing trends. Middle to upper housing types typically has a land area of 100 m$^2$ to 200 m$^2$ and a building area of 200 m$^2$ to 400 m$^2$. And from the Surabaya city climate analysis it can be concluded that the hottest month is October so that October was chosen to be conducted as a representative of the hottest month. Tropical houses have the following characteristics (table 1):

| Table 1. Characteristics of tropical architecture |
|-----------------------------------------------|
| Element | Characteristics                          |
| Wall and Opening | Walls are permeable with openings wider and transparent (with the aim of being more integrated with nature) |
| Roof    | Tropical architecture is also called roof architecture. The roof has a wide eaves because it functions as a shading device |
| Ornament | Using natural materials such as natural stone There is an additional canopy as a building shadow |

The above are characteristics of tropical architecture in general that have been applied to buildings in tropical climates even in traditional architecture. During the time, the elements were adapted and modified. The characteristics above are as a benchmark for determining the variants to be studied.

2.2. Sampling

The sample selection uses purposive sampling, which is deliberate sampling according to requirements (characteristics, criteria) and following the research objectives. This method makes it easy to select and eliminate until the sample becomes more conical. Filtering is intended so that the selected sample is more under the research specifications. The determination of variants is based on the general characteristics of tropical architecture as mentioned in table 1 so that the percentage of the reference elements becomes the main and largest percentage. If there are additions or modifications to these elements, it means that they are derivatives and the variants mean the extent to which modern tropical architecture adapts tropical architecture which is classified according to the percentage of each element. Based on the division of elemental suitability percentages with the original characteristics
above, it is divided into 3 variants namely A, B, and C. Following are the provisions for distribution of variants, Variant A has a percentage of 85-100% matching characteristics with original tropical architecture, variant B has a percentage of 75-85% matching characteristics with original tropical architecture and varian C has a percentage of 70-75% matching characteristics with original tropical architecture.

The percentage obtained from the suitability of aspects of the roof, walls and openings, ornaments, and sun shading in each tropical house. In a collection of several houses, 3 houses were taken representing modern tropical styles. From the above classification, houses taken as research samples with variants are shown in figure 1.

Figure 1. Samples of houses for each variant. (A) variant A, (B) variant B, (C) variant C.

2.3. Equality of comparison and simulation
After observing and measuring the field, modeling is done using simulation. At this stage, the simplification of houses that are above 1000 m² is done by eliminating secondary rooms so that there is only a primary room with an area that is not far from the others. The broad range to be compared is 730-864 m² with facade widths of 10-12 m. Modeling is created as real conditions of the building and space as possible to find out the true thermal conditions without using air conditioners and ignore the use of other electronic devices. The simulation is conditioned at the same time as the field measurement time to facilitate the verification process.

Autodesk Ecotect Analysis was used as simulation software in this study. Ecotect is a software for analyzing building design and environment that includes various simulation and analysis functions [13]. Simple, quite appropriate, and visually responsive are the characteristics of thermal performance analysis produced by Ecotect [14]. There have been many studies [15] [16] that have used this software to evaluate their studies. And to pay more attention to environmental issues, the Ecotect simulation received praise from several architects who helped achieve a design that could reduce the potential for global warming [17].

3. Results and discussion
The simulation of 3 buildings will be compared by analyzing the thermal conditions in the building. The first step is to make the modeling of the three buildings using predetermined comparative equality. The following figure 2 is the model results of the 3 selected buildings that represent each variant.

Figure 2. The modeling of 3 buildings. (A) variant A, (B) variant B, (C) variant C.
3.1. Thermal building performance all the house samples
Temperature conditions both inside and outside the building were analyzed based on the results of hourly temperature profile data on each sample of each variant. And then it is analyzed about degree hours, percent dissatisfaction, and thermal comfort level (time and comfort duration). The results of the overall simulation showing the 3 items can be seen in table 2 below.

| Style                | Degree hours (Kh) | Comfort duration (hours) | Percent dissatisfaction (%) |
|----------------------|-------------------|--------------------------|-----------------------------|
| Modern Tropical A    | 151.4             | 6                        | 31.3                        |
| Modern Tropical B    | 321               | 7                        | 100                         |
| Modern Tropical C    | 137.1             | 3                        | 97.9                        |

The first aspect that can be seen in the comparison shown in figure 2 is the degree hours. In the table, it can be seen that the accumulation that is above the comfort zone threshold of a sample of modern tropical homes is 151.5 Kh in variant A, 321 Kh in variant B, and 137.1 Kh in variant C. The smaller degree hours it indicates that the building has good thermal performance. Of the three variants above, variant C is the variant with the lowest degree hours so that the sample C variant shows the best performance. But the comparison's results on aspects of the comfort duration are different. In the aspect of comfort duration, the building that has the longest comfort duration is a building that has good thermal performance because it can protect and provide comfort to its occupants against the sensation of heat coming from outside the building. The longest duration of comfort is owned by a variant A home sample, it is about 7 hours. So in this aspect, the sample house of variant A shows the best thermal performance compared to the other two variants. It should also be noted that although all three samples have a comfortable duration, none of the duration is comfortable that meets the standard of comfort. In the last aspect, which was percent dissatisfaction, the overall results showed that the sample A variant had the smallest number among the others, which was only 31%. This shows that the sample A variant has the best performance. If all three aspects are combined that indicate the good performance and thermal comfort of a building, then the sample A variant has the best thermal performance and comfort because it fulfills two of the three aspects. The overall results show similarities in previous studies [12] that the application of passive design (adapted from traditional tropical architectural elements) can reduce thermal discomfort but cannot provide thermal comfort throughout the day (proven to only have a comfortable duration of 7 hours). And regarding the temperature in the room exceeding the limits of the thermal comfort standard, the study mentioned up to 80% but this time the research reached 100% (as evidenced by the absence of a comfortable duration that met the thermal comfort standard).

3.2. Elemental breakdown envelope building
In the simulation, there are results of breakdown between opaque elements and transparent with ventilation (Qs, and Qv) whose data is presented in numbers and graphic images in color gradations. The color gradation starts from blue as the lowest temperature indicator to yellow as the highest temperature indicator. Below is presented the data in the form of facade color gradations in front of the graphic to make it easier to see and understand. The following figure 3 and figure 4 are the simulation results for each sample.
Figure 3. Simulation results of façade sample house variant A. (A) east, (B) west

In the simulation data and visualized by the picture above, it can be seen which elements contribute the most to increasing heat (red box marks) in buildings and which contribute to reducing the heat in the building (blue square sign). The color indication not only shows the temperature on the building envelope but also the closest space behind it. Because of its location at the end of the road, the sample of this house has two facades so that the figure in figure 4 above has 2 images, of which one facade looks west and another facade looks east. On the second floor envelope, there is one side that contributes to the increase in heat, which is at the end of the middle meeting indicated by the yellow color. The side consists of wall elements and opening elements (windows) on both sides and there is a small shading on top. While on the envelope of the 1st floor, there are 2 sides of the envelope which have the smallest heat contribution, there are on the east and west sides. On the east side, there is portico (canopy terrace/balcony), while on the west side, only the wall element. It can be concluded that the opaque element is combined with elements of openings (windows) but only accompanied by sun shading with a size that is not suitable (small), less capable and less effective in driving away heat entering the building. It is also mentioned in previous studies that the number of shaded areas (produced by sun shading) on opaque walls is better than in glass windows [11]. Conversely, shading in the form of a portico can reduce heat even though there are openings elements. The opaque element, which is a wall that is not given an opening, also shows good performance because it can store heat and reduce it. In addition to the building body, the hottest part is the roof. The roof adapts the traditional roof of tropical houses that have wide eaves but are modified to be more modern and minimalist in shape. The modification turned out to influence the thermal entering the building.

Figure 4. Simulation result of façade sample house variant. (A) Variant B and (B) Variant C

The simulation results in the variant B sample indicate almost the same as the sample of the variant A. The side of the building which contributes to increase the heat is on the envelope of the 2nd-floor side corner. The side consists of wall elements and non-operable openings. And regarding the thermal properties material, the opening elements using aluminum frame material and glass which have the lowest specific heat value which means that the two materials cannot store large amounts of heat are the element that forwarded heat into the room quickly. This is not following previous research that
traditional architecture combined with modern materials will produce buildings that are more comfortable thermal up to 80% [5]. In the simulation results, it is shown that not all modern materials have a good contribution to thermal. Conversely, the adaptation of local materials commonly used in traditional architecture such as natural stone turned out to make a good contribution in dispelling incoming heat. This is indicated by the area marked by the blue box, which is the side of the bottom envelope. Natural stone as a coating of the outermost layer makes the area behind the side of the envelope cooler than the outside area. The roof area is the same as the sample A variant because it has the same shape so that the contribution of heat is the highest shown by the color yellow.

In the simulation results of the variant C house, the side of the envelope that contributes to heat is the side of the first floor at the far left. The side consists of wall elements and small vents. The combination of open walls and vents is also not the right combination to fix thermal problems. This is appropriate with the results of research which states that large and too open openings that are identical to tropical architecture are not always better (thermally) when applied [9]. Then the most contributing side to the thermal conditions is as in the sample A variant, which is the canopy area (terrace/balcony) and also the side of the wall which is entirely coated with natural stone. There is a difference from the side of the roof compared to the other 2 variants. In this C variant, the shape of the roof uses the original form of a traditional tropical design, namely joglo. Adaptations that only modify a little with a form that is broadly similar to the roof of traditional tropical architecture turned out to be more effective in fixing the problem of heat compared to roof designs of variants A and B.

4. Conclusion
Overall, a house with a lot of design that adapts traditional tropical architecture (variant A) is a house that has better thermal performance compared to a house that adapts slightly to traditional tropical architecture. Samples of variant A houses adapt and modify nearly 95% of traditional tropical architecture. A very important element to adapt and modify is the roof element (tropical architecture is identical to the roof architecture), the opening element that carries the permeable concept to traditional tropical architecture, ornaments that use natural materials, and also the most important sun shading that can protect the exposed sun area. The four elements can be modified following existing trends. Thus, tropical architecture no longer looks old fashioned but is more trendy while still paying attention to the heat issues that are characteristic of humid tropics and also the phenomenon of climate change that is becoming an environmental issue.

Acknowledgments
Thanks to BMKG Juanda Surabaya for provided the climate data used in this research.

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