Shady residency: Passive technologies through shading devices for some building styles to fix heat problem causes by climate change in a tropical area

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Abstract. The issue of Green Building arises after environmental issues that lead to global warming are echoed. All kinds of interpretations about green buildings are often associated with the building's adaptation ability to the environment including the heat problems. This research aims to evaluate shading devices in 3 building styles, namely Minimalist, Modern Tropical, and Mediterranean in how to respond to heat problems due to climate change and investigating shading devices that have the potential to be applied to all building styles by using the simulation method with ECOTECT software. The results mentioned that the area using the shading device in the form of a terrace or balcony with a canopy (horizontal or curve overhangs), either stand-alone or continuously upward like Portico in the Mediterranean style shows good performance in reducing the incoming heat. And that type of shading device is found in 6 of 9 house samples which indicate that this type of shading device can potentially be applied to various styles with modification of shapes according to each style.

1. Introduction

1.1. Building, environment, and techno-science
The issue of green building arises after environmental issues that lead to global warming are echoed. Now energy efficiency is considered important by many countries for the sustainability of the building sector so that the environmental impact caused by the energy sector can be reduced especially those related to climate change [1]. Therefore, all matters relating to the surrounding environment, such as the local climate, topography, and geology become concerns in building construction, building layout, and building envelope design [2]. The approach is carried out because the surrounding environment is responded by buildings in inflexible ways, one of which involves varying interactions with the local weather, then also with internal loads such as residents and equipment inside, heating or cooling systems and ventilation [3]. Energy consumption is mostly used for air conditioning and lighting systems, especially in hot climates [4]. This air conditioning system is also a cause and effect of the emergence of environmental issues that cause climate change which makes the air feels hotter in hot climates so that workers in the building sector try to create buildings that can protect from heat due to climate change but which do not worsen the environment and commonly referred to as green building.
As technology develops, all kinds of interpretations about the green building are often associated with intelligent buildings. An intelligent building does not have to always use sophisticated technology, but the intelligent definition states that adaptability is also a central aspect [5]. Because when technology is moved from one region to another, new people (in a socio-cultural context) will give different interpretations and meanings to the same technology so that social and cultural aspects are also likely to change too [6]. Therefore, the building's adaptation ability should be the highlight of the definition of the intelligent building itself. Thus, the facade and all elements in the facade as the outer envelope of the building have an important role in adapting to the surrounding environment, especially to the local climate. The Adaptive facade is a facade that allows changes in construction and can be adjusted by occupants even though no automation technology is applied [7]. And elements in the facade that have an important role in adapting to sun exposure and heat in hot climates are shading devices.

1.2. Shading device and thermal modernity
Shading devices are usually located behind the transparent parts of the building to protect the building from sun exposure and reduce heat from the outside. The transparent part of a building is usually in the form of windows and from all facade elements, windows have the warmest interior surfaces and the largest thermal fluctuations in hot weather [8]. The phenomenon of climate change makes the hottest states become even hotter and finally many buildings have been built with cool and comfortable rooms by adding air conditioning which until now has become increasingly sophisticated. Air conditioning has been used as a universal technique in overcoming thermal problems rather than paying attention to building design so that it can be said that air conditioning now has a role as an agent of architectural transformation [6]. Each architect's work should be scientifically processed and aware of the development of solar control devices so that buildings especially in hot areas are protected from the sun [9]. Speaking of the design of sun protection devices, before deciding what protective devices to use, it must be decided by the architect as to which zones will be protected and the period of protection from the sun's heat [9]. After it has been decided, to support the resolution of heat problems with no impact on the environment, a shade device should be chosen that follows a passive design approach so that no energy sources are involved, such as fixed and adjustable shading devices [10]. The use of shading devices with a passive design approach cannot be compared with the use of air conditioners because it cannot remove whole body thermal stress so there is a need for a new perspective on current environmental conditions where people might encourage them rather than avoid them as a source of discomfort [11].

The use of shading devices with a passive design approach, one of which is using fixed shading devices, is mostly found in residential buildings in tropical regions such as Indonesia, especially Surabaya. There are three residential building styles in Surabaya that are often encountered and commonly applied fixed shading devices, namely Minimalist, Modern Tropical and Mediterranean. Previous studies suggest that shading devices in the form of horizontal overhangs can reduce energy consumption by 14% in the east and west [12]. Other studies have shown that all forms of fixed shading devices (original horizontal curves, horizontal overhangs, vertical fins) will increase the duration of thermal comfort in the space if an egg crate is added [13]. Previous research highlights fixed shading devices as something that stands alone and is not associated with a building style that should be a single unit. So that research that links fixed shading devices as devices that use a passive approach to design with a particular style of residential buildings has not been done. This study evaluates the thermal performance of shading devices as a characteristic of a building style. It aims to find the best-performing shading device that allows it to be applied to several of these styles so that shading devices are not only seen as functions but also as aesthetic supporting elements of a style. And with the variety of styles that exist today, whatever style choices will be applied, this shade can be used with several adjustments.
2. Method

2.1. Buildings description
The subject that will be examined is the building envelope in Minimalist, Modern Tropical, and Mediterranea style and the object is a residence in Surabaya. Shading devices that are attached to a unity of a style and its performance in solving heat problems are examined in this study.

The type of housing being studied is middle to upper-class housing with a land area of 100 m² to 200 m² and a building area of 200 m² to 400 m² that has the potential to apply many styles to buildings because financially the owner has enough funds to renovate or build a house following existing trends. And October was chosen to research as a representative of the hottest month based on conclusions from the climate analysis of the city of Surabaya. Below are the shading devices in each style (table 1).

| Style           | Characteristics                          |
|-----------------|------------------------------------------|
| Minimalist      | Horizontal overhangs                     |
|                 | Vertical fins                            |
|                 | Secondary skin                           |
| Modern Tropical | Roof                                     |
| Mediterranea    | Original horizontal curve                |
|                 | Portico (Canopied terrace)              |

Above are shading devices that are generally used in each style. But so far in its application, some have been adapted, combined, and modified. The above characteristics are a benchmark for shading devices that are typical of a style that will be examined. The length and depth of each shading cannot be compared to the comparison because each is unique to each style so that what can be compared to the comparison is the space and building area as a result of the shading.

2.2. Sampling

| Sample  | Minimalist | Modern Tropical | Mediterranea |
|---------|------------|-----------------|--------------|
| Variant A | ![Image]   | ![Image]        | ![Image]     |
| Variant B | ![Image]   | ![Image]        | ![Image]     |
| Variant C | ![Image]   | ![Image]        | ![Image]     |
The use of purposive sampling for sample selection is intended so that the sampling under the requirements and follow the research objectives. Determination of variance is based on the general characteristics of shading devices that characterize an architectural style as mentioned in table 1. Based on the percentage distribution of conformity with the original characteristics above, divided into 3 variants namely A, B, and C in each of its styles. As mentioned in table 1, the match criteria with those mentioned are 85-100% for variant A, 75-85% for variant B, and 70-75% for variant C. From the above classification, houses taken as research samples with variants are shown in table 2.

2.3. Equality of comparison and simulation
The wide range to be compared is 730-864 m$^3$ with a facade width of 10-12 m so that simplification of the house is above 1000 m$^2$ by eliminating secondary space so that there is only primary space. Modeling is made as a real condition and ignores AC and other electronic devices. To simplify the verification process, the simulation is conditioned at the same time as the field measurement time. This research uses Ecotect software for simulation and thermal performance analysis. Ecotect software is used because the results are quite accurate and visually quite responsive and the analysis is simple [14]. Research relating to environmental and building aspects has used a lot of this software for their studies [15-17].

3. Results and discussion
The simulation of nine buildings will be compared by analyzing the thermal conditions in the building, especially on the envelope with shading devices. The first step taken is to create a nine-building model using predetermined comparative equality, then simulate it, and the final is analyze it.

3.1. Elemental breakdown of building envelope
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 3 below.

In the table above it can be seen that the left one is a thermal color gradient to indicate which side of the envelope has a low temperature even when exposed to the sun. In each style variant, there is one variant in which the building envelope does not indicate a low temperature. In the Minimalist Style in variant C, in Modern Tropical style in variant B, and the Mediterranean style in variant C. That means that the shading device used has no impact and does not solve the building's thermal problems. And 6 out of 9 variants, which detected low temperature in the envelope of the building, almost all of them use shading devices in the form of canopy terraces either only on the first floor of the building or continuously upwards. And in the thermal color gradient, which shows blue and is marked with a blue square line is part of the building envelope that has shading devices in the shape of a canopy terrace that only exists on the first floor of a building or continuously upwards. This indicates that shading devices in the form of horizontal overhangs on terraces and balconies, especially those that continue, have a good impact on the thermal conditions of buildings because they can reduce the heat shown in blue on the gradient. Shading devices in the form of overhangs on windows that are either horizontal or curve, do not show a significant effect on heat reduction. And when seen from the graphs $Q_s$ and $Q_v$, on the building envelope whose shading device is not functioning properly, it also has a significant impact on buildings related to thermal conditions. This is in line with the results of research that says that indoor thermal conditions are affected by shading devices [18]. The shading device does not affect, most of the time there is a temperature surge during the day that the building should need protection from heat and it happens in many rooms in the building. The heat conditions outside the building which are accumulated with the heat conditions inside the building will cause thermal discomfort to the occupants especially during the day. Terrace and balcony provide a separate room for the opportunity to reduce
the heat that will enter the building while the canopy or overhang shading device fends off direct sunlight entering the building.

Table 3. Samples in each style.

| Sample              | Thermal Color Gradient | Shading Device | Qs + Qv |
|---------------------|------------------------|----------------|---------|
| Minimalist Variant A| ![Image](image1)        | ![Image](image2) |         |
| Minimalist Variant B| ![Image](image3)        | ![Image](image4) |         |
| Minimalist Variant C| ![Image](image5)        | ![Image](image6) |         |
| Modern Tropical Variant A | ![Image](image7) | ![Image](image8) |         |
| Modern Tropical Variant B | ![Image](image9) | ![Image](image10) |         |
| Modern Tropical Variant C | ![Image](image11) | ![Image](image12) |         |
| Mediterranean Variant A | ![Image](image13) | ![Image](image14) |         |
| Mediterranean Variant B | ![Image](image15) | ![Image](image16) |         |
| Mediterranean Variant C | ![Image](image17) | ![Image](image18) |         |

4. Conclusion
Shading devices in the form of a terrace or balcony with a canopy (horizontal or curve overhangs) are effective in reducing heat entering the building. And that shading device models are almost always in every building style, which is 6 out of 9 sample houses. So that shading device model has the potential to be applied to all residential building styles by adjusting its shape according to each style.

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