Optimization of Heat Gain in Vertical Housing Design for Middle Low Economy, Cengkareng-Jakarta Barat

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ABSTRACT
This paper discusses the optimization of heat gain in vertical housing design for the middle-low economy, using rhino, grasshopper, and ladybug simulation. This study aims to explore a vertical housing design that minimizes heat gain, optimizes view, and increases wind speed. The methodology of this research is quantitative, through an experimental method, namely by making a geometry model according to field conditions in the math model (rhinoceros simulation), then simulating solar radiation gain (heat gain) through grasshopper & ladybug simulation. The research step: (1) to analyze microclimate and site context, (2) to make model design simulation-based on Kampong structure (horizontal housing), (3) to analyze the radiation gain in the simulation model. (4) to recommend geometric shapes for the most optimal vertical housing gain of solar radiation (heat gain). The results show that from the simulation of 3 models based on the kampong structure's geometry, the most optimal form is the shape that minimizes the orientation of East and West. Modular geometry is the L-shaped shape of the kampong structure module and each floor is laid out on each floor in the opposite direction, thus casting a shadow on each floor. The final form result also provides optimal views and increased wind speed that can dissipate heat.

Keywords: *Optimization, Heat gain, Vertical housing, Simulation.*

1. INTRODUCTION

Tropical climates have specific problems where the outside temperature is above the thermal comfort of building occupants. The average temperature is above 30^{0}C, humidity is 80-100%, and high humidity and high solar radiation gain. The average temperature is above 30^{0}C, and humidity is 80-100%. Then the occupants of the building feel a hot thermal sensation [1]. Achieving thermal comfort for building occupants will affect energy use in buildings in particular and urban energy in general [2-3].

Energy consumption in buildings contributes to the largest energy use (52%) of all energy use worldwide [4]. Rapid urban growth and continuous high urbanization. This has the effect of increasing energy in urban areas. The density, type, and size of buildings in an area are important factors in determining energy consumption. The relationship between the shape of the city will have an impact on energy consumption [3-9]. Settlements in urban areas also shape urban patterns, which affect urban energy. Urban thriving settlements are high-density settlements that develop organically within the city. These urban kampongs are often part of a slum and wild area, with small houses in high density. Horizontal urban kampung in the geometric form [3,10], will get higher solar radiation (heat gain) than vertical buildings. Because the largest gain of solar radiation (heat gain) is obtained from horizontal radiation. The heat gain will affect thermal comfort and energy use [11]. The increasing density and limited land give the idea of the redevelopment of middle-low economy housing from horizontal to vertical housing [12]. Dense horizontal dwellings or urban kampungs with current conditions do not meet the quality of life for the community and also do not meet thermal comfort [13]. Whereas the needs of thermal comfort in urban villages rely on passive design. Alternative settlement of urban villages with a vertical kampung design strategy by taking into account thermal comfort and liveability. For urban settlements, with a vertical housing design strategy that meets comfort and quality of life [14]. To reduce heat gain by exporting building geometries in particular and urban geometries in general [15]. This paper will discuss the optimization of heat gain in vertical housing designs. The objectives of this paper are:

- To identify the urban kampung structure and, interpret it into a vertical residential model for a middle-low cost.
- To make a computational simulation to produce an optimal design to minimize the gain of solar radiation.

The research methodology used is a quantitative methodology with experimental methods using rhinoceros, grasshopper, and ladybug simulations [16]. While the structure of the paper will explain the paper related to the conditions of the urban kampung, vertical housing, microclimate, and thermal comfort. Then experiment set up which will explain the stages of the research process. And discussion of the results that will provide recommendations for optimal vertical housing geometric shapes.

2. THEORY AND FORMULA

Rearrangement of urban kampong housing into vertical housing can provide changes in urban form modification [17]. This can reduce energy use in cities by 26% worldwide [18]. The decision to change and design a dwelling at first is very important because this design decision will affect the time of construction and the impact after the dwelling is operational. The redevelopment of vertical housing should improve and reduce uncomfortable spaces, and make housing feasible and healthy [19-21].

To achieve thermal comfort and energy-efficient building, one of the strategies is to use physics-based simulation building performance. One of the variables is designing buildings that can minimize heat gain. So that initial design decisions will have an impact on energy use and thermal comfort in buildings [22-24], and on an urban scale [25,26]. Simulation by simplifying the actual form into a replica, it is necessary to set an input with a mathematical model and the right algorithm (rhinoceros and grasshopper). And then the model is simulated against local climatic conditions (ladybug). The defined model is less able to provide design results and predictions of energy use in buildings that are not suitable and also on thermal comfort [23,26]. So at the initial stage, it is necessary to determine in advance the parameters to be discussed and the response to the microclimate and site context. And what parameters will be reviewed? Geometry form factor, building orientation, ventilation [27] in building and urban scale [28].

Specific parameters for the optimal geometric shape of the energy consumption in the building [28], and thermal comfort [27]. As well as conditions when the building is operational [27]. And other parameters that can be seen beside the main parameters, namely natural lighting [24] and ventilation [27]. Parameters that have been selected for optimization can be used as a basis for assessing, either partially or completely [27].

It is also worth noting the use of building performance simulations in developing countries according to the specific climatic context and location [28]. The partial use of simulation is used for the needs of private buildings as a basis for determining the use of energy consumption and the selection of heating or cooling in the room to meet the occupants' thermal comfort and energy consumption [29].

Specifically, research on thermal comfort in developing countries and humid tropical climates is different from the others, especially for middle-low housing. Where using passive cooling such as fans and natural ventilation [12]. This is a challenge in itself where the thermal environmental conditions will affect the thermal in the building. So that all year round with a certain design can optimize passive cooling: natural ventilation to provide comfortable indoor environmental conditions [11].

3. EXPERIMENTAL SETUP

This research methodology used quantitative approaches, through experimental methods. It used rhinoceros, grasshopper, and ladybug. Detailed experiment set up (figure 1). Then research step divided:

- The first, to analyze microclimate and site context on Kampong Kota Cengkareng, Jakarta Barat.
- The second, is to make a model design simulation based on the Kampong structure (horizontal housing).
- The third: to analyze the radiation gain in the simulation model
- The fourth, is to recommend geometric shapes for optimizing vertical housing gain of solar radiation (heat gain).

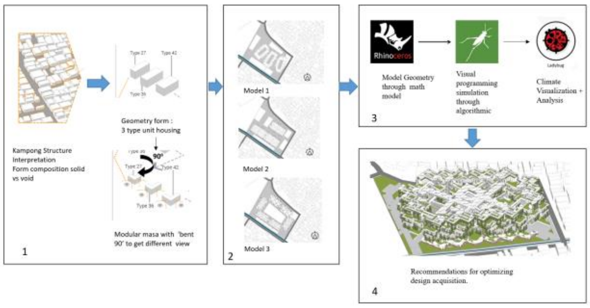


Figure 1 Experimental setup of optimization of heat gain in vertical housing design.

4. RESULTS AND DISCUSSION

4.1. Micro Climate and Site Context Analysis

The location of the horizontal urban kampung is in Cengkareng, Jakarta. Jl. Kapuk Kampung No.142, RT.9/RW.12, Kapuk, Cengkareng District, West Jakarta. Kampung Kota is a dense settlement with high density, the distance between buildings is quite close, with small roads and simple rectangular mass forms with an area divided into 27 m2, 36 m2, and 42 m2. The order of the mass is close and tight, access to outside space is only at the front of the building. Composition of mass and open space (solid & void). The shape and arrangement of the masses of each house in this area is an irregular grid pattern. A small road in the form of an alley with a distance of 1-2 meters, forms a corridor.

The distance of buildings that are dense and close, so that sunlight in the morning and afternoon is blocked, except for houses that are on roads that can be passed by vehicles. Houses that are right in front of the main road tend to be better in terms of responding to climate criteria with a roof that is suitable for tropical climate conditions in the East and West, rather than the North and South orientation.

Source: Google map.

Figure 2 The location of dense urban kampung settlements and the location of vertical residential sites (red area).

4.2. Climate Data

Climate data for the West Jakarta area is obtained from the EPW point of Soekarno Hatta Airport. The wind speed in the site area shows that the highest wind speed is 2.67 m/s and the lowest is 1.48 m/s. The dominant wind direction is from the South West and Westside. Wind speed from Soekarno Hatta's EPW data in urban kampung conditions is relatively low. The average temperature data is between 25 ℃- 35.8 ℃. The high temperature starts at 11.00-15.00 which is between 31.5℃-35.8 ℃. This indicates that the outdoor temperature is above the thermal comfort temperature. Likewise, the average relative humidity is quite high, 80-100%, especially in January and February.

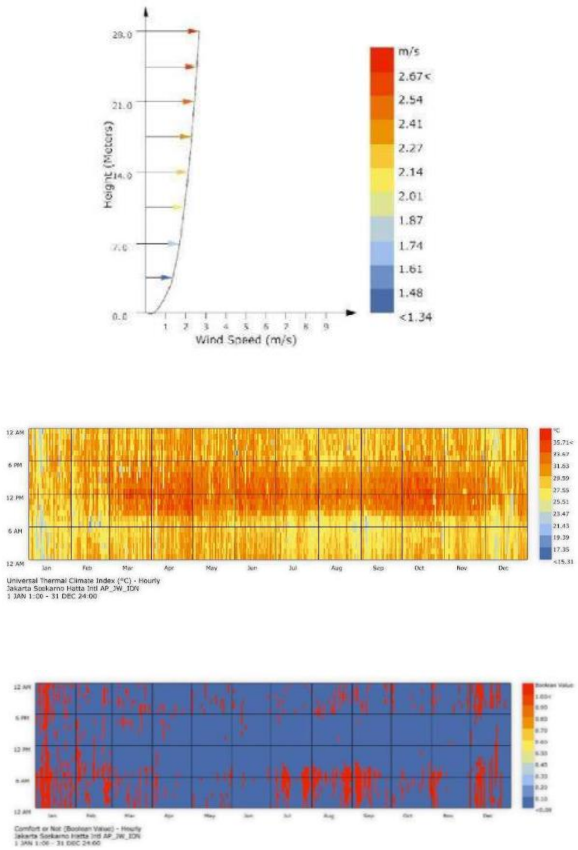


Figure 3 Climate data graph.

4.3. Geometry Models and Optimization of Heat Gain in Building

The results of the location and microclimate identification, a proposed model of the geometry model that responds to the site is made. The three forms are from the transformation of solid void existing conditions of dense urban kampungs into 3 forms to optimize heat gain in vertical housing.

4.3.1. Composition of Solid Void Geometric

The results of the location and microclimate identification, a proposed model of the geometry model that responds to the site is made. The three forms are from the transformation of solid void existing conditions of dense urban kampungs into 3 forms to optimize heat gain in vertical housing.

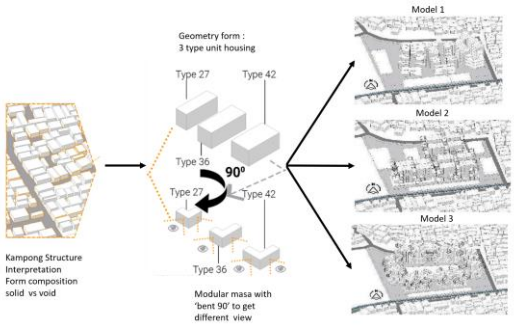


Figure 4 Composition of solid-void geometry.

4.3.2. Composition of Solid Void Geometric Shapes

- The 1st shape solid void geometry mass composition by forming 3 blocks. Each block has an open space void, facade orientation on the East and West sides.
- The 2nd shape solid void geometry mass composition by forming 3 blocks. Each block has an open space void, facade orientation on the North and South sides. The short facade of the East and West is expected to reduce heat gain.
- The 3rd shape is different from the 1st and 2nd shapes. The mass block shapes are put together, with large voids. The shape of the building mass is made a paradox between floors so that the shadows form between the geometric shapes of each floor.

4.3.3. Heat Gain in Vertical Housing

The shape of the solid void geometric mass that is different on each floor (layer per layer) is a very optimal form to minimize heat gain in the building (third form). The paradoxical form of each floor where the geometric shape of each floor or layer forms a canopy (shade) that overshadows the shape below it. This shading reduces the heat gain in each unit mass of vertical residential buildings.

Globally, a form that responds optimally to site context and climatic conditions. The orientation of the building with the longest facade on the North and South sides, and the short facade on the West and East sides minimize heat gain from the highest solar radiation direction, namely the Westside. The large void shape optimizes the flow pattern on each side of the building facade on the inside and outside of the building. So that solar radiation in the building envelope can be removed by wind speeds that occur in the microclimate.

Table 1 shows the minimum solar radiation obtained in model 3. The highest radiation exposure on the horizontal roof which in the optimization of advanced designs will be used as a solar panel as a renewable energy source. Similarly, the heat gain on each side of the facade, the geometric shape that gets the lowest solar radiation in the third geometric shape.

Table 1. Comparative analysis of geometric models 1, 2, and 3

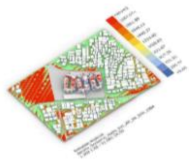
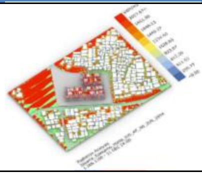
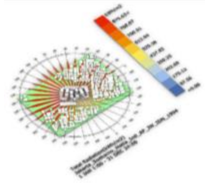
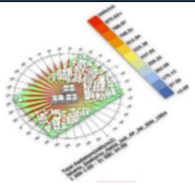
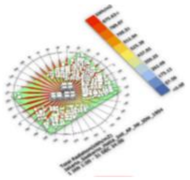
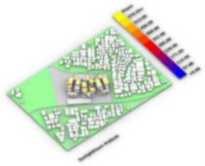
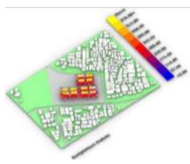
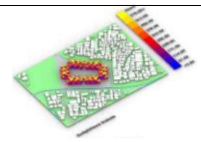
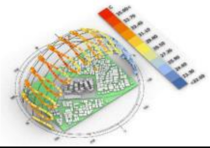
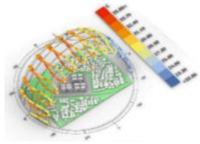
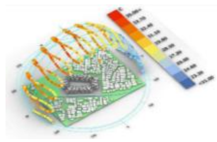
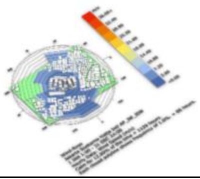
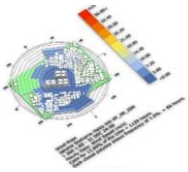
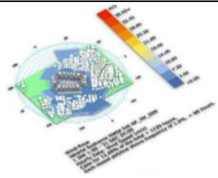
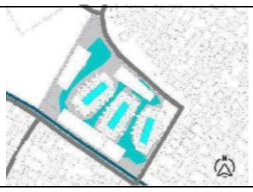
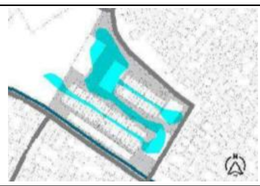
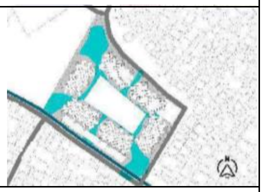
Analysis	Model 1	Model 2	Model 3
Solar Radiation			
	249 kwh/m2	209 kwh/m2	192 kwh/m2
	The roof of the building is directly exposed to radiation which will be used as a source of solar panel energy.		

Table 1. Cont.

Analysis	Model 1	Model 2	Model 3
Radiation Direction			
	875 kwh/m2	788 kwh/m2	788 kwh/m2
	The shape has responded to site conditions and microclimate, the second and third forms of solar radiation gain are the same because the orientation of the longest sides of the facade is in the North and South. However, solar radiation in model 3 is reduced by geometric shadows between buildings on each floor.		
UV Exposure			
	570 Hour	570 Hour	570 Hour
	The building is exposed to direct sunlight all year round.		
Sun Movement			
	The direction of the sun moves horizontally and is responded by placing the shortest sides of the building on the East and West sides.		
Wind Direction			
	The orientation of the building has responded to the direction of the wind on the site from the southwest and west. All forms optimize the gain of wind flow into the site.		
Ventilation System			
	The three forms of the building are designed to respond to the wind and optimize the wind entering the site. Voids are designed in each model to optimize natural ventilation on each side of the building.		

5. CONCLUSION

This paper explores the design of vertical housing which starts from the interpretation of the geometric shape of the horizontal urban kampung structure. Vertical housing modelling with optimization criteria of solar radiation heat gain. Vertical housing for medium-sized economies takes into account economic conditions, thereby optimizing passive cooling into buildings. The results showed that the 3 models formed from the interpretation of the solid void urban kampung structure. The shape responds to climatic conditions, paying attention to the orientation of the building, minimizing the facade area in the West and East orientations, to minimize the acquisition of solar radiation. Model 3, which is the model with the largest voids and the most dynamic geometric shape, is a very optimal model to minimize the heat gain of solar radiation. The paradoxical shape between the floors (layers) creates a canopy that shadows each other between geometric shapes, thereby helping to reduce solar radiation gain.

Exploration of geometric shapes to optimize solar radiation heat gain, with rhinoceros, grasshopper, and ladybug simulations can be done by making various models. This simulation greatly helps predict more efficient designs, optimizes passive cooling, and saves energy. The simulation model will improve design decisions for low-cost vertical housing. Furthermore, it can be used as the basis for making low-cost vertical housing regulatory policies. The next research can develop the proposed computational energy modelling framework for more detailed vertical housing. Then can support global research on sustainable cities, sustainable housing, low carbon and energy efficient building.

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