Integrating Green Building Criteria Into Housing Design Processes Case Study: Tropical Apartment At Kebon Melati, Jakarta

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Abstract. The implementation of Green Building criteria is relatively new in architectural practice, especially in Indonesia. Consequently, the integration of these criteria into design process has the potential to change the design process itself. The implementation of the green building criteria into the conventional design process will be discussed in this paper. The concept of this project is to design a residential unit with a natural air-conditioning system. To achieve this purpose, the Green Building criteria has been implemented since the beginning of the design process until the detailing process on the end of the project. Several studies were performed throughout the design process, such as: (1) Conceptual review, where several professionally proved theories related to Tropical Architecture and passive design are used for a reference, and (2) Computer simulations, such as Computational Fluid Dynamics (CFD) and wind tunnel simulation, used to represent the dynamic response of the surrounding environment towards the building. Hopefully this paper may become a reference for designing a green residential building.

1. Introduction
High-density residential buildings consume a huge amount of energy. The major cause of this phenomenon is the building’s inability to adapt with the local climate. This buildings has a thermally uncomfortable rooms, thus force the tenants to use artificial air conditioning system.

To reduce and minimalize the use of energy on a high-rise residential building, a prompt design that can create thermally comfortable buildings is needed. To achieve this design, green building criteria needs to be included since the beginning of the design. To optimize the building’s design, a guidance tools are needed for a better understanding of the building’s actual condition. The guidance tools in this case study are simulator software that can simulate the thermal condition of a buildings and the airflow around the building. Several theories made by experienced professional who already applied in built projects are also used as a guidance tools.

This paper will describe the process of implementing green building criteria in a traditional design process.

2. The design process on tropical apartment project.
The case study is located at Kebon Melati, Central Jakarta. Jakarta is located on wet tropical area which has a constant high intensity of sun radiation and has moderate rainfall intensity, except for the
winter months, when it becomes very heavy due to monsoon season. Most importantly, Jakarta has an average high temperature (28°~31°C). Consequently, the usage of artificial air conditioner becomes common. Through this design process, several green building criteria, based on tropical architecture principle, will be used to design a residential building which can minimize air conditioner usage.

On this case study, the green building criteria will be integrated with traditional design process in order to change conventional process into a more advanced process to developed integrated green building. The traditional design process can be explained in below diagram:

The green building criteria implemented on every stages of the traditional design process. These criteria enter as a requirement that must be fulfilled by the design itself. These criteria also cannot be detached from each other. It means that without fulfilling all the criteria, the green building system cannot be optimal.

On the massing stage, the green building criteria requires the design to adapt with existing physical situation of the site, such as solar chart, air temperature, and airflow. Following the initial design of the massing, a macro simulation, using Autodesk Flow Design software, is performed for a major comprehension of air circulation surrounding the massing. The results of this simulation will become a feedback in order to achieve the optimum design. These feedbacks will determine the ideal distance between the mass, and the massing composition.

Having the feedbacks implemented on the massing, the layout of the residential units inside is developed. Subsequently, these layouts will be taken to a micro simulation process to determine the horizontal and vertical zoning of the unit’s layout to design the cross ventilation system inside the unit. In this stage, Thermal Mass theory is starting to be implemented on the unit’s layout.

The last stage, facade study, is where the theories of Thermal Mass and Night Cooling will be implemented. The implementations of these theories are an important stage in this design process. This stage will show the result of green building criteria intervention towards a traditional design process.

3. Massing Stage
Primary and secondary data regarding the site and building’s typology were collected during the early stage of massing process. These data contained government regulations, building codes, standards, precedent, and site analysis. The green building criteria at this stage help to design a mass that respond
to existing site condition based on site analysis. These conditions were air temperatures, solar chart and airflow. These three conditions were the main variable within this stage. The air temperature inside the building must be lower than the outside and the airflow surrounding the building help to lower the air temperature inside the building, but still maintaining the comfortable condition for human activity.

![Figure 3. The initial stage on massing process.](image)

The massing designed to minimalize solar radiation absorption through building’s envelope while adapting with existing airflow around the building. According to the solar chart on Figure 4, the sun rise on east, and set on west. It indicates that the east and west side of the building’s envelope will gets direct solar radiation. To avoid this situation, the building mass had to elongate from east to west to minimize the area of the east and west building’s envelope.

![Figure 4. Solar chart on existing site at Kebon Melati.](image)

Figure 3 describe the process massing to control the airflow around the building. Building’s massing divided to three parts in order to create gaps between the massing, this gap will allow the air to move around the building, and enter the building. To control the air movement so the airflow will not be too high, the massing designed to be ridged. The massing’s sides also made rounded to make the building aerodynamic, thus the air movement will be closer to the building’s skin.

4. Massing Composition

The mass composition stage is an advanced process of the building’s massing design stage. This stage determined the composition and the gaps between building masses, which divided into three in the previous stage. The distance between these massing will be decided based on the airflow around the building.

Airflow in an environment has a great influence to human comfort, especially on the physical environment 1.5 meters above the top of the terrain where the human activities occur. Table 1 shows the correlation between airflow and human comfort condition. Generally, a person feels comfortable with 1 ~ 5 m/s airflow [1]
Table 1. Airflow and human comfort condition.

| Airflow (m/s) | Level of comfort    |
|--------------|---------------------|
| <1           | Idle                |
| 1 ~ 5        | Comfortable         |
| 5 ~ 10       | Uncomfortable       |
| 10 ~ 15      | Very uncomfortable  |

The airflow simulation ran on the initial building massing design and utilizing Autodesk Flow Design software, which offers the wind tunnel simulator tools and enabling flow analysis around the building mass. Below is the result of the simulation process:

Figure 5. The simulation's result: airflows around the massing.

The result shows that the movement on the building’s surface has deep blue color, which indicates the airflow there is below 1 m/s. This deep blue color mainly found on the indented side of the massing. This condition made the deep blue area has a poor air quality as the air scarcely has any movement there. Furthermore, to induce the surface cooling system, the airflow around the building’s skin should be quite high. The yellow color on the massing gap indicates an area with the airflow around 3.1 m/s. This area will be connected with a sky bridge and will be used as an amenities area.

Even though based on Table 1, the airflow rate 3.1 m/s still can be considered a comfortable condition, but to utilize this area for human activities, there must be an adjustment on the design.

Figure 6. The revised design of the building massing.

These results were used as feedbacks for the design, and several adjustments were made based on these feedbacks. First, the initial massing were made to be less ridged and minimizing the cramped area which has a poor airflow rate. To lower the airflow rate in between the massing, the building surfaces that facing each massing were made to be more ridged and the habitable zone was located on the indented part of the massing. The distance between the massing was considered to be sufficient as
the air movement can be detected on that area. Figure 6 is the revised building massing after adjustments based on the simulation feedbacks:

Figure 6 present the revised massing design based on the feedbacks from the airflow simulation. The outer surface of the massing, marked by red-lined square, is made of smooth surface without any indented part. This smooth building surface is expected to make the air flowing as near as possible to the building skin, thus can help cooling the building interior. This phenomenon is called surface cooling system.

Furthermore, the gap part of the whole building massing is made to be rougher, and has several indented part on the surface to slow down the airflow. By doing this, the gap part will have more comfortable airflow rate hence can create a comfortable condition for human activities. Balcony and openings are also located throughout this area. As a result, the air that will enter the residential units is expected to be a comfortable, breezy, fresh air with low airflow rate.

5. Zoning
A vertical zoning for the building massing is designed to equip the horizontal mass which has been done in the previous stage. Figure 7 shows the vertical zoning of the building mass.

![Figure 7. The building massing's vertical zoning.](image)

The three massing of the tower will be connected by sky bridges, which function as a bridge between each tower, and an amenities area for the units above. Furthermore, this area is also equipped with a refuge area as a shelter for future emergency situation.

Following the completion of the vertical and horizontal zoning for the building massing, the interior of the residential area is developed through a horizontal zoning. This zoning was made on the schematic floor plan of the residential units. The important part of the zoning stage is to determine the concept of the cross-ventilation system. On the schematic floor plan, several openings is located on the opposite to each other to follow the passive design strategy. Having done that, the micro simulation for further understanding of the cross-ventilation design is done. The simulation is conducted using a software called Autodesk Computational Fluid Dynamics (CFD) which is a simulator to visualize how a liquid affects objects as it flows past.

This simulation will determine the openings placement, as well as to decide the location of each room. Prior to that, when the room schedule is arranged, it is distinguished by its needs to be equipped with air conditioner or not. The rooms which need to be air conditioned are the bedrooms. Formatting author affiliations
Please ensure that affiliations are as full and complete as possible and include the country. The addresses of the authors’ affiliations follow the list of authors and should also be indented 25 mm to Table 2. Room schedule of three bedrooms unit.

| 3 Bedrooms Unit       | Area (sqm) |
|-----------------------|------------|
| Master Bedroom        | 24         |
| Bedroom 1             | 14         |
| Bedroom 2             | 14         |
| Dry Kitchen           | 9          |
| Dining Room           | 20         |
| Living Room           | 28         |
| Master Bathroom       | 8          |
| Bathroom 1            | 6          |
| Balcony               | 9          |
| Maid Room             | 8          |
| Maid Bathroom         | 3          |
| **Total Area**        | **143**    |

The rooms that are highlighted with yellow are the one equipped with air conditioner. The rooms that are not equipped with air conditioner will be located on the area where fresh air can freely flow to the rooms so that the temperature inside the room can be lowered. Whereas the rooms which will be equipped with air conditioner will be located on the area with minimum airflow.

Prior to micro simulation process, the openings on the units are determined and is distinguished by the inlet and the outlet. The simulation’s result is shown below:

**Figure 8.** The micro simulation results using CFD simulator.

Figure 8 indicates the schematic floor plan with the inlet and outlet openings plan. The colour spectrum on the figure 8 indicates the airflow rate, and the curved line is showing the airflow according to the designed inlet and outlet.

The area with the deep blue colour showing that the airflow rate there is around 0 m/s. Thus, the area with the deep blue colour, which located mainly on the corner area, will be placed rooms with air conditioner system. The area coloured with lighter blue will be functionalized as rooms with cross-ventilation system since the lighter blue indicates the airflow with 2~3 m/s rate.
From the simulation result, the feedbacks for the schematic floor plan are applied to the design. Bedrooms are located on the north side of the unit, where the simulation result shows deep blue color. Living room and other less private rooms are located on the area with good airflow rate that indicated with lighter blue colour in the simulation result.

To help decrease the interior’s air temperature, the thermal mass theory is applied on this design process by choosing a suitable wall material. Thermal mass is a material’s ability to store and release heat energy. The principal of thermal mass can help to control the energy flow on the building to make the building more energy efficient. A material’s thermal mass determine the material’s ability to absorb and release heat. On this case study, which has the goal to design a residential building that minimize the usage of an air conditioner, a material which absorbs minimal amount of heat on the day and release maximal heat is the most ideal and beneficial for this case study.

A lightweight material, like aerated concrete blocks and gypsum, is a material which has a low value thermal mass, which means it has a low heat absorption capacity. Meanwhile, a heavyweight material, like brick and concrete, is a material which has a great capacity to absorb and release heat. This kind of materials performed as a thermal collector if it is facing east or west. They have relatively high heat-capacity value and automatically influence the thermal environment effectively as heat absorber or heat emitter [2]. Combining these two sorts of materials can built a system which can be utilized as a system to reduce the air temperature inside the building.

The east-west wall collects the heat from direct sunlight and release the heat to the air, while north-south wall may collect the heat indirectly from the air. Therefore, the lightweight material will be used on the east-west side building envelope.

Both the lightweight and heavyweight material will be used in this building. Aerated concrete block with aluminum composite panel as an exterior facade material is categorized as a lightweight material, whereas concrete and brick wall is used as a heavyweight material.

Figure 9. Thermal mass absorb heats on the daytime (left) and release heat during nighttime [3]

Figure 10. Floor plan of three bedrooms unit.

Figure 10 shows the location of heavyweight and lightweight walls. The solid black line shows the heavyweight walls, and the white one shows the lightweight wall. Rooms that are considered more private than the other rooms are located on the north side of the unit, where the openings are rather
small and equipped with air conditioner system. Less private room, such as living room, kitchen and dining room, is created as an open layout room which the future tenant has the freedom to adjust the layout. This also makes the rooms has a bigger space thus the air can flows freely as the room has no partition.

To expedite the airflow and maximize the cross-ventilation system on the unit, a large opening is placed as the main source of fresh air. Furthermore, this opening is already modified to adapt with weather changes. To ensure that the air can enter the unit and flows, an exhaust fan is installed as the outlet of the airflow. The scheme of the cross-ventilation system is shown below:

![Figure 11. Inlet and outlet plan on the unit.](image)

6. Study on Building Envelope Systems.

The green building criteria on the opening’s design are based on the integration of thermal mass theory with a passive cooling system named night cooling system. The integration of these systems can help optimizing the passive cooling system on the unit.

Taking the advantages on thermal mass, the air temperature can be decreased by using the help from walls and floor slabs. The ideal condition to release the heat and cooling down happens on the night time. Therefore this system is called night cooling system. The basic concept of night cooling system involves cooling the building structure overnight in order to provide a heat sink during the occupancy period [4,5].

The night cooling system utilize the low temperature on the night time to cools down the walls and floor, thus on the next morning the room’s temperature is lower, and can maintain the cool ambience. To establish this system, the openings and the air intake has to be designed. On the night time, the openings has to be opened maximum, thus the heat absorbed by the wall and floor materials during the day time can be released, and replaced with cool air. On the morning, the openings should be close and kept minimal openings so that the cool air absorbed the night before can be kept and the air temperature maintained to be low.

The implemented night cooling theory is followed by the modification of window’s design. The night cooling and thermal mass system is a mutual and continuous system, and therefore the openings designs are adjusting with the integration of both systems.

The openings have two conditions depending on the time. On the night time, the openings can be opened maximum thus can encourage the fresh air to enter the unit and cools down the air. On the day time, the openings should be kept minimum so that the fresh air can flow inside without absorbing too much heat.
Figure 12. The passive cooling system work scheme on the night time.

Figure 12 shows the unit condition at night:

- Every openings are opened, thus the cool air with low temperature from outside can enter the unit.
- The low temperature air cools down the released heat from the wall and floor. Subsequently, the low temperature air absorbed by the walls and floors.
- The cool air released by the air conditioner also cools down the heavyweight walls and then transfer the low temperature towards the non-air conditioned rooms, thus can helps decreasing the air temperature.

On the day time, the low temperatures on the rooms should be kept by closing the openings and reducing the opportunity of heat absorption. Hereafter, the walls and floors will be absorbing the heat again. Thus, the openings must be kept open to a minimum degree for cross-ventilation to be happening.

7. Conclusion

The design process of Tropical Apartment at Kebon Melati, Jakarta, consist of conventional design process, which is commonly used, and then integrated with several green building criteria to answer the design’s goals. The criteria of green building itself affect the design fundamentally. Since the building massing stage, the application of green building criteria has been used and the building masses are automatically formed due to the urgency to meet these criteria.

Therefore, in a building design process of a green building, the green building criteria itself is the most important part, and can be called as the core principle of the design and cannot operate optimally if the criteria are not considered and included from the early stages of the design process.

The rapid development of technology on the field of architecture, construction and material engineer, encourages architects to be able to design not only visually aesthetic buildings, but also has a good impact on the environment. In the future, the implementation of the green building concept can no longer be avoided. Nevertheless, this does not mean a limitation for an architects. In the end of the day, designing a building that is visually aesthetic and implementing the concept of green building is very feasible.

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