Night ventilation at courtyard housing estate in warm humid tropic for sustainable environment

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Abstract. The problem in the night-time for warm humid tropic housing estate is thermal discomfort. Heat gains accumulation from building envelope, internal heat gains and activities of occupants influence indoor thermal comfort. Ventilation is needed for transfer or removes heat gains accumulation to outdoor. This study describes the role of an inner courtyard to promote pressure difference. Pressure difference as a wind driven force to promote wind velocity thereby could transfer indoor heat gains accumulation to outdoor of building. A simulation used as the research method for prediction wind velocity. Purposive sampling used as the method to choose building sample with similar inner courtyards. The field survey was conducted to obtain data of inner courtyard typologies and two housing were used as model simulation. Furthermore, the simulation is running in steady state mode, at 05.00 pm when the occupants usually close window. But the window should be opened in the night-time to transfer indoor heat gain to outdoor. The result shows that the factor influencing physiological cooling as consequences of inner courtyard are height to width ratio, the distance between inner courtyard to windward, window configuration and the inner courtyard design-the proportion between the length, the width, and the height.

1. Introduction
Economic growth in Indonesia led to the structure of the Indonesian middle class that has a pyramid format [1]. The problem that arises along with the ability of middle-class on energy consumption for fulfill thermal comfort. This ability is a factor supporting the high use of cooling energy for the housing estate in Indonesia. Increasing the use of active cooling in occupancy needs to be taken seriously in order to reduce operational energy consumption and control carbon emissions, while also playing an active role in climate change. This energy is used to meet the needs of cooling and lighting. Increased thermal comfort is needed by residents in tropical urban housing, and it requires housing estate design that is can to meet these aspects. Efforts to reduce energy use and reduce carbon emissions in the urban housing sector are to condition the house in a physiologically cooling. If the housing estate design can accommodate these needs, it is suspected to reduce the use of cooling energy.

This paper describes the role of inner courtyard in Surabaya housing to increase the flow of the wind in the bedroom and living room connected with the inner courtyard uses two houses as simulation models. The goal is to extend the thermal comfort range or to achieve physiological cooling. In the humid tropics, the inner courtyard is an open space within a housing estate unit. The presence of open spaces in housing estate can promote the pressure difference. It can generate wind flow. Microclimate conditions also have a role in improving the flow of wind.
In dry climates, the inner courtyard serves as an internal orientation. Consists of several housing estate units oriented to the inner courtyard. Some research on courtyard is related to aspects of thermal performance only [2].

Thermal comfort is primary a condition that expresses satisfaction with the thermal environment. Air temperature is the dominant factor in determining thermal comfort [3]. The thermal comfort in the room depends on the temperature of the outdoor. Neutral temperatures are a basic that can be used to provide thermal comfort. The thermal comfort range is at +/- 2.5K from the neutral temperature. Physiological cooling express extending of thermal comfort zone that relies on wind flow [4]. Opening windows to drain the wind is one of the adaptations to comfort [5] [6].

Housing is one of the principle human needs. As a place of living, it must fulfill health and comfort requirements. Lighting, ventilation (air temperature) and humidity in space will influence thermal comfort. One of the efforts predicted to be able to fulfill these three factors is the availability of inner courtyard. Internal courtyard of house will improve comfort zone if space have external openings to the environment. It shows that the influence of the courtyard on the thermal condition has reliance on the envelope openings [2]. The addition of trees or/and galleries to the closed courtyard significantly improves the outdoor comfort. Under the assumption of constant building temperature of 25 degree, the addition of galleries is the most efficient shading strategy. Quantitative results exhibiting these trends are show specific configurations and orientations of ventilated and shaded courtyards [7].

Night ventilation in addition to eliminating the heat load in the room is also required to be able to control the indoor humidity and the concentration of CO2 gas. It level can be tolerated up to 70% [8]. Night ventilation can be used to modify indoor air temperature with thermal mass effect if the average daily temperature is higher or exceeds the comfort limit. This condition is expected to help the process of heat transfer. Night ventilation intended to provide physiological cooling should have an outdoor temperature lower than the comfort limit. Night ventilation as a strategy to prevent heat accumulation and to remove heat load from the indoor to outdoor of the building as physiological cooling for the humid tropics.

2. Method

The simulation method is used to obtain wind flow data in the inner courtyard, and Ansys CFD as a tool to show air movement [9]. Calculation model uses RNG k-ε and standard wall treatment. The simulation is conducted in steady state condition, i.e., at 05.00 pm. In the field conditions, the occupant starts closing the window at that time, which should have the window opened for generating heat transfer by convection from indoor the building to the outdoor.

A method for determining housing estate samples is purposive sampling. One criterion is the width of the site from 8 to 12 meters and has an inner courtyard in the beside or behind of building. This study uses two samples that represent houses that have an inner courtyard in Surabaya. The location of two samples is in the urban lowland area, and lie in housing with a grid pattern. It plays a role in the formation of wind direction for all objects which is parallel to the road or parallel to the building.

Site width is 12 meters, and its length is about 18-22 meters and inner courtyard position on the side or back of the site. The inner courtyard geometry is square whereas the inner courtyard dimension is about 1/3 of the width of the site with a depth of about 1.5-3 times the width of the site. The height of the inner courtyard barrier walls is 7 -9 meters in average.

3. Results and Discussions

High humidity is one characteristic of humid tropical climate. One of the strategies that can be applied to reduce humidity is cross ventilation. Two factors influence cross ventilation, namely building and environmental. Among them is surface roughness type, building mass order, building orientation to the wind, the height of the building, roof geometry and opening design and thermal mass of buildings [10]. In urban areas, the available air velocity is relatively weak compared to the perimeter.
The design of outer space including the canyon design influence the success of the natural ventilation system [11]. Canyon design affects microclimate conditions outdoor buildings and indoor buildings. Research on canyon design is related to shading in the dense urban environment, but it describes the condition of canyon design that is the ratio of H/W (height to width ratio) and canyon for L/H (canyon length to height ratio) to the air velocity at night day. Air velocity that occurs in outer is directed to contribute to the indoor air velocity, where the inner courtyard presence will show in its role in creating pressure differences to distribute air velocity in modest housing in humid tropics.

Urban geometry can express as a value or H/W ratio. The H/W ratio is the ratio between the mean height of the building and the width of the street [12]. The H/W and L/H canyon ratios have a significant correlation to the type of the wind in outdoor or environment [13]. According to [13] classified of the wind type into three types of skimming flow, wake interference flow, isolated roughness flow. Skimming flow follow when the ratio H/W > 1, Wake interference flow occurs when the ratio of H/W ≤ 0.5 and isolated roughness flow occurs when the ratio H / W <0.3.

![Figure 1. Object 1: H/W 0.52 and the canyon L/H 22.](image)

As shown in Figure 1., Object 1 has an H/W ratio of 0.52 and is located in the L/H 22 canyon getting the wind with wake interference flow type. In wake interference flow conditions, the available wind velocity outdoor the building at 04.00-05.00 pm averages is about 1.3-1.7 m/s.

Lower ratio of H/W and L/H of a canyon, the air velocity that occurs outdoor the building will be greater, this situation provides opportunities for the use of natural ventilation in the room. Ratio 0.4 <H / W <0.6 is the ideal condition for creating thermal comfort for urban areas with medium latitude (15-30°).

The inner courtyard position of this object is located in the back. The dimension of the courtyard is 4.5 meters depth, 9 meters width, the height of the inner courtyard barrier wall is 9 meters. With such geometry has a chance of space facing the inner courtyard. The rooms connected with the inner courtyard are the bedroom, terrace, and kitchen. All openings in the rooms are connected with inner courtyard then provide opportunities for the cross ventilation system [14]. Thus, it is expected to accelerate the process of heat transfer from indoor the room to the outdoor of the building.
The simulation is aimed to predict the distribution of air flow due to the presence of inner courtyard, when at the same time all windows are open. In fact, the residents close the window during the day until night. The simulation conducted at steady state at 5:00 pm when the wind orientation is parallel to the building.

The simulation results in Figure 1 shows an increase in air velocity as it passes through openings in the indoor of a building that indicates a considerable pressure difference. Air velocity backs down in the family room (the middle). There is an increase in air velocity as it passes through openings leading into the inner courtyard. It shows that the inner courtyard can promote the occurrence of differences in pressure, to create a uniform wind distribution for all parts of the building.

Air velocity through openings in the living room is 0.4-0.8 m/s, while for the bedroom is around 0.6 m/s. On the back terrace near the openings is about 1.1 m/s, decreases to 0.7 m/s. With air velocity of 0.6 to 1.1 m/s, it can provide enough passive cooling, especially in the living room and terrace. In addition to air velocity, the distribution of air flow is also evenly distributed in the living room and back porch.

The existence of several openings serve as an inlet, then the speed of the wind into space can be distributed more evenly. The distribution of air flow from outdoor into indoor of the building follows the theory of continuity. It is influenced by different pressure; the existence of a large pressure difference then air velocity will increase. However, at some point, it does not get enough air flow. The opening position also affects the distribution of air flow in the room [6]. In addition to the design of openings, the presence of inner courtyard plays an important role in creating pressure differences. Differences in pressure can occur in the outer room with the living room, then continued to the living room with the inner courtyard. The configuration of space that forms the wind aisle helps increase pressure differences and create higher air velocity.

The second object has a ratio of the H/W 0.55 and the canyon L/H 18 (Figure 2.). With the urban geometry as mentioned, it is classified on the wake interference flow type. Privileges on this object have two inner courtyards, which are located on the side and the back.

In the inner courtyard on the side, the connected spaces are the living room and kitchen. For the inner courtyard in the back of a building, the connecting rooms are the main bedroom, the child's bedroom, and the toilet. The simulation results show the window opening position that forms the wind corridor can increase air velocity. It can form the alley of the wind if one room with another space is in connection with a window or a door that continuously. In this case, space between inner courtyard, kitchen and service room formed wind corridor.

If the spatial configuration does not form a wind corridor, then the air velocity into the room decreases. To increase wind speed and to distribute air flow more evenly into the space. It is required the proper arrangement of the opening position, that show in the living room. It has 0.6 - 1.1 m/s as highest air velocity for near the openings.

Two bedrooms on the second model faced to the inner courtyard. With this condition, openings can face the inner courtyard. Based on the simulation results, air velocity can meet the needs of physiological cooling even that the distribution is not evenly distributed throughout the bedroom. Arranging the opening configuration will distribute wind distribution more evenly.
4. Conclusions
Based on the simulation result of the housing estate which has an inner courtyard, several factors influence the distribution and opportunity of air flow in indoor of building, that are the outdoor environment factor and the building design. Outdoor space factor is the ratio of building height to the width of the road or the ratio of H/W, the lower the ratio, the greater chances of getting air velocity. The next factor is the inner courtyard position which is located on the side or in the behind of the building, the position of the opening is toward the inner courtyard. The inner courtyard position in the side has a potency to increase the indoor air velocity more than the back inner courtyard. The position of openings located in a straight line will form a wind corridor. It can increase the air velocity but all parts of the room cannot receive the same wind distribution.

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