Wind-Driven Natural Ventilation Design Of Walk-Up Apartment In Coastal Region North Jakarta

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Abstract. Housing has been the second most energy-consuming sector in Indonesia nowadays. According to the data released by government, the biggest consumption in housing sector is the use of air conditioning. This consumption will significantly rise in metropolitan-high density city like Jakarta along with the increase of vertical housing supply. This research focus on design iteration to achieve optimum model of wind-driven naturally ventilated housing. Cilincing District, North Jakarta, known as industrial and settlement area is used as case study. Since the location by the bay area, Cilincing represents the characteristic of tropical coastal area. This research utilizes the tropical coastal characteristic especially wind to design a naturally ventilated housing. Various building elements are determined as variables and tested using Ansys Fluent CFD simulator to achieve thermal comfort standard by SNI 03-6572-2001. Preliminary results shows that unlinear (zig-zag) building layout and combination of various building distances give big impact to airflow movement around the buildings. Narrowing building distance in the middle of the site can create a kind-of tunnel / trap that strengthen the wind along the site. Inlet and outlet area should be balance to avoid uneven airflow distribution inside the room and located in different level to maximize cross-ventilation.

1. Introduction
Energy consumption of South East Asia is increasing nowadays. Indonesia, country with the highest population number in South East Asia, spends energy the most among other countries [1]. Household is the second most energy-consuming sector after industry in Indonesia. The Ministry of Energy and Natural Resource releases data which states that in household sector, energy is mostly used for air conditioning (ventilation).

Meanwhile, this energy consumption will keep rising along with the increase of housing needs, especially in big city like DKI Jakarta. Therefore, we need a housing solution that can save energy especially for ventilation.

To fulfill housing demands, the goverment of DKI Jakarta sets a program to build vertical housing, mainly for middle-class society which is still dominating the income distribution of Jakarta [2].

Location is an important issue in housing design. Development of Jakarta is slowly moving toward the north area. One of the example is massive reclamation plan along North Jakarta coast. In Nort Jakarta, Marunda Village in Cilincing District can be a perfect location because it suits with goverment’s plan (RDTR DKI Jakarta) to develop this area into vertical housing zone. This area has lower density than other districts and the land price is affordable, but already has good infrastructure.
and public facilities. This location is also predicted will continue to grow as industrial centre along the reclamation of O, P, and Q islands as the Port of Jakarta.

Adjacent to Java Sea, this location has a strong character of coastal region. Based in local data from BMKG Tanjung Priok, this area has monsoon climate with average wind velocity 2 m/s mostly comes from north-east, average temperature 28°C, and humidity between 64.58 – 85.17% around the year.

The availability of sunlight and wind in coastal tropical area is a potential that can be utilized to produce a thermally comfortable, energy-efficient building design using natural ventilation.

1.1. Walk-Up Apartment
Walk-Up Apartment is a vertical housing which use stair as the main vertical transportation system. Elevator is not mandatory and each block usually consists of 12 – 40 units [3]. Other characteristics of walk-up apartment are: walkable; units usually accessed by interior hallway; each unit has private outdoor space (such as balcony / patio); off-street or basement parking.

In Indonesia, walk-up apartment can be categorized as rumah susun (rusun). There are some classification of rusun but this project focuses on the design of low-rise, middle-class, commercial rusun. This typology has been commonly applied in other countries but to fit with Indonesian habitational behaviour, there are some adjustment needed, such us the unit size (1 bedroom 24 m² unit and 2 bedroom 36 m² unit are chosen), the existence of private open space (balcony in every unit) as a substitution of garden in landed housing, also spacious corridor (corridor width 1.8 metre) and community room in each floor.

1.2. Thermal Comfort
Air conditioning, the main issue of housing energy consumption in Indonesia, is an artificial way to achieve thermal comfort using mechanical utility. The key to achieve thermal comfort is maintaining the body temperature between 37°C [4]. Human preference of thermal comfort may vary but SNI 03-6572-2001 has set a standard as written below.

| Theory            | Temperature (°C) | Wind (m/s) | Humidity (%) |
|-------------------|------------------|------------|--------------|
| SNI 03-6572-2001  | Comfortable cool20.5-22.8 | 0.1 - 0.35 | 40-60         |
|                    | Optimum comfort 22.8-25.8  |            |              |
|                    | Comfortable warm 25.8-27.2  |            |              |

There are some environmental factors of thermal comfort: air temperature, radiant temperature, air movement, and humidity. The most effective way to achieve thermal comfort in tropical area is optimization of wind movement because the breeze allows heat dissipation on the surface of your body [5].

This project located on the coastal area which has dominant wind characteristic, so the design iteration and simulation will focus on thermal management through wind-driven natural ventilation.

1.3. Wind-Driven Natural Ventilation
Wind-driven natural ventilation occur when higher wind velocity hits the building surface and creates higher air pressure (+) on the inlet and lower pressure (-) on the other side. This pressure differences on the building’s surface will initiate air to move across the building, bring the fresh air and also reduce room temperature [4]. From the literature study, we conclude that atrium or courtyard can penetrate sunlight and improve the quality of natural ventilation. Chosing atrium-shape mass also allow the application of double-side or cross ventilation where inlet and outlet are located in the opposite direction with each other.
Air movement around building is affected by its environment. There are some variables that will affect air movement around the building: 1) Building form \([6, 7]\); 2) Orientation \([8, 9]\); 3) Building layout \([7]\); 4) windscoop \([6]\).

Inside the room, hot air moves from the bottom and flows near the ceiling, waiting to be removed and replaced by fresh air. There are also some variables that will maximize air movement inside the building: 1) Opening dimension \([6] \text{ and } [10]\); 2) Opening orientation \([11]\); c) Inlet & outlet location \([6]\).

2. **Design Case**
This project is located near North Jakarta beach, in Marunda, Cilincing District, Indonesia. This area is proposed as vertical housing zone in RDTR DKI Jakarta and surrounded by green area, schools and industrial zone. The site has 1.4 Ha area and will have maximum 35% built floor area. Density that will be achieved is 460 persons/Ha, so we will have 6 blocks 5-storeys buildings with 288 room units/block.

3. **Design Simulation**
Simulations are done using Ansys Fluent Simulator in order to test the effect of variables mentioned before to get optimum design model of wind-driven naturally ventilated housing.

3.1. **Outdoor Simulation**
The data assigned in the beginning are wind velocity 2 m/s, temperature 28°C, and wind direction from north-east. The first simulation is a step to check the general wind behaviour around the site effected by the surrounding buildings in radius 250 metre. The site (inside rectangle) is barely shaded by other building so wind can still move freely inside the site.
Table 2 Model 1 and 2 in simulation.

| (1.a) Rectangular | (1.b) Square | (2) With Pilotis |
|-------------------|--------------|------------------|
| ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) |
| $V = 1.487681 \text{ m/s}$ | $V = 1.5416522 \text{ m/s}$ | $V = 1.5423875 \text{ m/s}$ |

The second variable tested is building shape. Rectangular shape is better because wind can be distributed evenly along the building surface. From the simulation with the same capacity atrium model, we can conclude that between rectangular (1.a) and square (1.b) plan model, there isn’t significant difference on wind behaviour. But 1.a model is still better because in square model, there are some units that face east – west which can increase heat radiation inside the building. Larasati (2000) on Seftyarizki [8] also stated that lifting building mass (creating a pilotis) will create better airflow inside the building which has been proven in simulation model 2.

The next simulation tested the effect of orientation to wind distribution around the building. Burnett [5] proposed to test three different orientation $0^\circ$ (3.a), $45^\circ$ (3.b), $90^\circ$ (3.c). From the simulation we can see that 3.b has the best result where there is less shadowed area (more light-blue colour). But 3.b model need a lot of space and doesn’t fit with the building regulation. Model 3.a and 3.b both have wide dark-blue areas, but model 3.c are all facing east – west so 3.a is chosen.

Table 3 Model 3 in simulation.

| (3.a) $0^\circ$ | (3.b) $45^\circ$ | (3.c) $90^\circ$ |
|-----------------|-----------------|-----------------|
| ![Image](image4.png) | ![Image](image5.png) | ![Image](image6.png) |

Table 4 Model 4 in simulation.

| (4.a) | (4.b) | (4.c) | (4.d) |
|-------|-------|-------|-------|
| ![Image](image7.png) | ![Image](image8.png) | ![Image](image9.png) | ![Image](image10.png) |

Fourth variable to be tested is building layout. For tropical region, unlinear building layout is better because it will create courtyard where airflow can pass around the buildings [9]. Each alternative has
different value of distance between buildings. Combination of distance between buildings in model 4.d gives the best result (indicated by light-blue colour).

Model 4.d gives a good airflow around the buildings, but there are still some dark-blue areas in the gap between the buildings. Windcatcher is added in model 5, formed by the extension of building cores. This feature directs and splits airflow to evenly move inside and around the buildings.

![Figure 3 Model 5 in simulation.](image)

3.2. Indoor Simulation

From the last iteration (model 5) we take data of velocity in the longer-side facade of the building, 1.4 m/s, which will be the new input for the following iterations. Due to the limitation of Ansys Modeler, in this simulation, the room model is simplified so the result is only valid for undivided room such as kitchen, dining, and living room.

The sixth variable is opening dimension. Model 6.a with dimension 0.6x1 metre, is the basic opening size taken from the existing rusunawa. This model gives enough velocity inside the room but concentrated only in inlet and outlet area. Changes made in model 6.b by expanding the outlet area as big as 0.6x0.9 metre. This changes gives much better result because airflow is distributed more evenly.

Baker (1987) in Seftyarizki [8] stated that window-to-wall ratio (WWR) of two opposing windows should be 20% each. So in model 6.c the opening size is expanded to 0.6x1.5 metre, giving a slightly slower velocity but with worse airflow distribution. In model 6.d, smaller opening dimension (0.6x0.8 metre) is tested which gives almost the same airflow result as 6.b but with higher air velocity.

| (6.a) | (6.b) | (6.c) | (6.d) |
|-------|-------|-------|-------|
| V = 0.6848 m/s | V = 0.7000 m/s | V = 0.6992 m/s | V = 0.712 m/s |

From the last iteration, model 6.b is considered as the best alternative but the velocity is still higher than SNI standard.

The next variable to be explored is opening location. Theoretically, inlet and outlet should be located in different side and different level to maximize cross-ventilation. In model 7.a, output is moved to higher level so hot air near the ceiling can be directly removed from the room. But this model has a problem because fresh air moves straightforward to the outlet. The air velocity is also still high and inhabitant can feel uncomfortable because air enters directly to their face or chest. So in
model 7.b, inlet is separated into two location so fresh air can be distributed better and moves vertically, sweeping the room from below and exits in the upper outlet. This alternative gives air velocity of 0.36 m/s inside the room with temperature of 27°C, so thermal comfort by SNI has finally been achieved.

Table 6 Model 7 in simulation.

| Model 7a | Model 7b |
|----------|----------|
| ![Image](7a.png) | ![Image](7b.png) |
| \( V = 0.6806 \text{ m/s} \) | \( V = 0.3654 \text{ m/s} \) |

4. Discussion and Conclusion
From all the simulation that has been performed, we can conclude that building layout can give big impacts to airflow movement around the buildings. In model 4.d, the combination of building distances (wide – narrow – wide) create kind-of trap or tunnel that strengthen the wind in the middle of the site, so we get a constant wind velocity along the site. Unlinear (zig-zag) layout also allows wind to move in the small gaps between buildings producing better airflow. Windcather such us slanted or soften building corner is an effective method to direct wind, which can also be an interesting architectural element.

With smaller WWR than 20% we can still produce a good quality of airflow inside the building. In cross-ventilation, inlet and outlet area should be balance because a big difference of inlet and outlet WWR can cause uneven distribution of airflow inside the room. Opening location is also an important variable in controlling airflow. Lower inlet location and higher outlet location directs airflow to sweep along the room, maximizing cross-ventilation, and creates a more comfortable condition for inhabitant.

With passive design interventions, thermal comfort can be achieved especially by wind-driven natural ventilation. We can also reduce the usage of mechanical utilities to obtain thermal comfort. Along with the increase of housing supply, we hope this research can be a solution to reduce housing energy consumption.

In this paper, only energy for ventilation that has been researched and simulated quantitatively. With further research in other aspects of energy efficiency, this research can be developed as a design guideline for an energy-efficient vertical housing.

5. References
[1] Agency International Energy 2015 *Southeast Asia Energy Outlook 2015* (Paris: IEA)
[2] Statistik Badan Pusat 2015 *Statistik Indonesia 2015* (Jakarta: Badan Pusat Statistik)
[3] 2005. *Housing Types.* (Minnesota: College of Architecture and Landscape Architecture, University of Minnesota)
[4] Larasati Dewi 2000 *Sunshading Design Method on Preliminary Design Stage for Multi-storey Building* (Bandung: Thesis of Master Program, Institute Technology of Bandung)

[5] Baker Nick 1987 *Passive and Low Energy Building Design for Tropical Island Climates* (London: The Commonwealth Secretariat)

[6] Szokolay S 2001 The building envelope In A. Krishan, N. Baker, S. Yannas and S. Szokolay (Ed.) *Climate Responsive Architecture 1st ed.* (New Delhi: Tata McGraw-Hill Publishing Company Ltd.)

[7] Thomas R, Garnham T 2007 *Environments of Architecture: Environmental Designing Context* (New York: Taylor & Francis)

[8] Caesariadi T W, Kalsum E 2011 Climatic responsive in Melayu Pontianak House *International Conference Local Wisdom in Global Era* UKDW Yogyakarta

[9] Seftyarizki D, Yasin M P E, Wonorahardjo S 2016 Optimizing Natural Ventilation in Designing Budget Hotel for Thermal Comfort in Bandung *Arte-Polis 6 International Conference* 309-318

[10] Burnett J, Bojić M, Yik F 2005 Wind-induced pressure at external surfaces of a high-rise residential building in Hong Kong, *Building and Environment* 40 (6) 765–777

[11] Nielsen K 2007 *A Design Guide for The Built Environment in Hot Climates* (London: The Cromwell Press)

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