The performance of ventilation in internal buildings affected by differences of building orientation

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Abstract. Natural ventilation is a passive cooling strategy with maximize of airflow into the building. Profil of hills and building orientation are some factor that influences the air quality, and it can control the wind speed. By the author’s previous research that building with configured in a grid pattern on the contoured land has enhanced the airflow quality than the grid pattern applied on the flat land. That condition affected building adaptation, such as good position of the opening in the building can optimize the utilization of airflow as the refreshment. This study purposed to evaluates performance of building ventilation of grid patterns on the hillside. This study using Jacky Chan Settlements that was located in Neuhen, Aceh Besar, Aceh Province, Indonesia. Computational Fluids Dynamics (CFD) Fluent used to analyze how far the performance of ventilation in the internal building. This study found that the pattern of airflow and the airflow quality in the room influenced by orientation. All orientation in the settlements created good cross ventilation with differences in wind speed. Contribute of this study is can be a reference for designing better settlements in a contoured land.

Keywords: Building Orientation, Computational Fluids Dynamics (CFD) Fluent, Ventilation

1. Introduction

Energy consumption is mostly absorbed in residential homes, where houses consume the largest energy of 28.8% of all energy consumption in the development sector [1]. Design adaptation to climate condition is can overcome excess energy consumption. Make use of airflow with a natural ventilation system is one solution that can minimize energy consumption. It can choose as passive control before use active system. Plan and orientation are other solutions that can considered as one of the adaptations to the physical environment [2].

The Ground surface condition effects to determine building configuration. It can change the behavior of air movement, which is it can accelerate the airflow even slow [3]. Radiation, wind, and topography are the main factors that determine building configuration. It can affect to consider the building orientation remain to protection of the sun, utilization of cross ventilation, and layout [4]. Minimize of sun radiation and maximize natural ventilation are the solution to building orientation in hot humid areas [5]. Differences in building orientation were influence to hit convection, wind speed and temperature [6]. Wind occurs because the heat of the sun that warms the air and the rotation of the earth, so that the air rise and move from one place to another [7]. The principle of the air movement is consists of [8] [9] [10]:

a. Reason the flowing air. This condition occurs because of differences in temperature. In this condition, the air moves from low pressure to high pressure.
b. Inertia. The air can be deflected because there is a barrier without influence a certain angle

c. High and low-pressure area. The air can be deflected because it prevented by vegetation and building.

d. Bernoulli effect. Acceleration flow needed to cover one form of building

e. Venury effect. Acceleration flow when through the opening with limited laminar flow

f. Stack effect. The exchange of air with natural convection caused indoor temperature higher than outdoor temperature.

g. Cross ventilation. This occurs when inlet and outlet openings in external walls have an internal flow path between them.

In addition, to distribute the fresh air into the room, natural ventilation also can dissipation of heat and give physiological cooling effect [11]. In choosing and designing of site to optimize the natural ventilation should be considered:

a. Take advantage airflow pattern with considered topography and building configuration

b. Conditioning of comfort in winter and summer

c. Avoid permanently for undesirable wind

d. Avoid highly wind velocity

e. Avoid the path of the wind that causes dust and pollution

The characteristics of the behavior of air movement are velocity, direction, and turbulence [10]. Air movement occur cause of surface condition that can divert the wind. That condition was forming freestream flow (laminar), shear layer flow (separated) and wake flow (turbulent) [3] [10]. Another factor that can divet the wind and change the wind speed is orientation, building dimension, overhangs and roof form (Figure 1).

![Figure 1. wind flow around the building (5) (9)](image)

Orienting buildings with certain angle to the wind direction can produce relatively homogeneous wind patterns. That orientation will affect airflow and wind velocity. In contour land, the grid pattern building that arrayed linear and angular to windward will create airflow better than grid pattern building in flat land. Based on that theories, optimization of the refreshment of the air highly building orientation, so that can reduce overheating in the building. This research-based on Author’s previous research, that have done at the same location.

There are two types of natural ventilation that cross ventilation and single-sided ventilation. The flow of Cross ventilation is determined by the combined effect wind temperature difference. It depends on other openings on opposite side of the building (Figure 2). Single-sided ventilation occurs when large ventilation openings are situated on one external wall only. Exchange of air occurs by wind turbulence when outward openings interacting with the local external airflow and stuck.

![Figure 2. Effect of size of inlet and outlet on internal wind speed and distribution (9)](image)
The location and orientation of obstacles can influence wind speed and airflow in the building (Figure 3). Parallel obstruction to windward will affect air movement [9]. Cross ventilation can be enhanced by obstacle, position of outlet in the sidewalls of building, and by the use of wind walls (Figure 4).

![Figure 3](image-url) Sealed enclosure, multi-opening sealed single side, and single side unsealed enclosure [9]

![Figure 4](image-url) airflow affected position of opening and obstacle [10]

2. Methodology
The simulation method was utilised for this research. The CFD Fluent Simulation used to see the influence of contour and building orientation to airflow in the room. The location of this research is in Jacky Chan Settlement, Neuhen, Aceh Besar, Aceh Province, Indonesia. This settlement consists of three different building cluster orientations that arranged in grid pattern. The simulation model in this research is representation of house model in each orientation. The building area in each housing is 45 m².

Collecting data for this research is climate data such as wind speed and wind direction. Another date is the existing of Jacky Chan Housing Unit related layout, opening position and building orientation (Figure 5.). There are four openings in the model. This research purpose to evaluate the influence of opening position in building toward performance of ventilation. The analyze for this research are:

a. Wind speed that occurs in the building
b. Performance of ventilation in internal building

![Figure 5](image-url) Existing of modeling for simulation (Authors survey, 2015)
3. Result and Discussion

3.1. Wind Velocity in The Building

The major of the wind speed is occur in Northwest-Southeast orientation (Table 1 and Table 2). In that orientation, wind speeds were created is 0.2 m/s - 1.1 m/s. The lowest of the wind speed is 0.2-0.6 m/s that occur in O1. That speed occurs in Southwest-Northeast orientation. Based on the above explanation, it is known that the angels of the building influence the wind divert. The principle of movement occurs is the inertia principle, where the existence of obstruction can deflect of airflow and it will influence wind velocity \[9\]. An average of wind speeds that occur in the room is 0.2 m/s – 0.6 m/s.

| Building Orientation       | O1   | O2   | O3   | O4   |
|----------------------------|------|------|------|------|
| Southwest-Northeast       | 0.2-0.6 | 0.4  | 0.2  | 0.4-1.4 |
| West-East                  | 0.2-0.4 | 0.2-0.8 | 0.2-1 | 0.2-1 |
| Northwest-Southeast       | 0.2-0.8 | 0.2-1.1 | 0.2-0.4 | 0.2-0.8 |

Table 2. The contour of wind in the building

| No | Orientation       | Contour of wind |
|----|-------------------|-----------------|
| 1  | Southwest-Northeast | ![Contour Image](image1) |
| 2  | West-East         | ![Contour Image](image2) |
| 3  | Northwest-Southeast | ![Contour Image](image3) |

Information: O = Opening

3.2. Performance of Ventilation in Internal Building
The performance of ventilation has been reviewed by wind direction, wind speed, and airflow that create in the room. Table 3 shows about wind vector and wind direction that create in the room. Based on that result, it will be known positive area and area in the opening. The positive area is inlet and the negative area is outlet. The positive and negative area that happened depend on orientation and opening position to windward. The dimension of opening also influences airflow that occurs in the room. From four opening there are in the building O1 is the biggest opening than others.

**Table 3. Wind vector in each building orientation**

| No | Orientation          | Wind vector |
|----|----------------------|-------------|
| 1  | Southwest-Northeast | ![Diagram](image1) |
| 2  | West-East            | ![Diagram](image2) |
| 3  | Northwest-Southeast  | ![Diagram](image3) |

**Information:**  
O = Opening

### 3.2.1. Southwest-Northeast Orientation

In the southwest-northeast Orientation (Table 3), the positive flow is just created in the opening 1 (O1), while in another opening (O2, O3, O4) are created the negative flow. This is because opening 1 (O1) parallel to windward. In the opening 2 dan 3(O2 and O3) the wind just flowing in the wall surface. In this condition, natural ventilation is occurring from opening 1 (O1) to opening 4 (O4). Opening 4 is the outlet. In the room occur the air reduction and then the air flowing into O4. Wind speed is rise in the opening 4 (O4) with the wind speed is 1,4 m/s. That occurs because venturi effect, where occurs the acceleration flow when through the flow of freestream.
3.2.2. **West-East Orientation**

There are two inlets in the building with west-east orientation (Table 3). The wind direction is parallel to Opening 1 and Opening 2 (O1 dan O2). Natural ventilation directly creates airflow from O1 to O3. In the middle room, the wind speed is declined, and airflow is slow. The wind speed returned increasing in O4 achieving 1 m/s. The venturi effect also occurred in this orientation.

3.2.3. **Northwest-Southeast Orientation**

In Northwest-southeast orientation, wind speed in inlet (O1 dan O2) is higher than other orientations. The flow is compelled because one corner of the building facing to windward. The inlet (O1 dan O2) is also parallel to windward, so that is creating airflow to the room. This condition is happening according to inertia principle. O4 also occurs the venturi effect with an increase of wind speed 0.2-0.8 m/s. Natural ventilation also creates from O1 to O3.

4. **Conclusion**

The conclusion of the performance of ventilation analyze are:

a. The best Natural ventilation was created in opening that parallel to windward. That condition produces the airflow that optimum to cooling space.

b. The building that angled against to windward will deflect the flow and the airflow to the building surface. The deflect of airflow that influenced by the obstruction is occurred inertia principle.

c. In the outlet (O4) was create a venturi effect. That condition causes the wind speed is rise, where occur the acceleration flow when through the flow of freestream. O4 is smaller than other openings, so that will create air reduction in the room, however in O4, the wind speed is rise due to venturi effect.

d. All of the building orientation in the Jacky Chan Housing is to create the best cross ventilation.

e. The factor that influences the performance of ventilation is topography, building orientation to windward, dimension of opening and position of opening.

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