Study on natural ventilation performance in flats design at Banda Aceh

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Abstract. Flats are one of the solutions to housing problems faced by all countries in the world, especially developing countries like Indonesia. Flats are intended for low-income society. But ventilation problems often occur in some vertical housing due to non-optimal layout and lack of openings in each unit. The cheapest solution is to optimize the natural ventilation to expediting air circulation from inside to outside. The purpose of this study is to review natural ventilation performance in flats design at Banda Aceh. Natural ventilation offers healthy and comfortable air circulation without additional energy. The performance of natural ventilation is affected by the building’s layout and orientation, the opening’s orientations, locations, dimensions, types and the air-flow controller. The methodology used is the observation method with a descriptive survey that aims to look for symptoms with an observation method. The study begins with a field study and then conducts an analysis to compare existing conditions with theoretical studies. The results obtained are the design of these flats has been designed to be able to maximize the natural ventilation system, but the air movement cannot be felt by the occupants due to the opening’s dimensions which is not following the existing standards.

1. Introduction

Flats are one of the solutions to housing problems faced by all countries in the world, especially developing countries like Indonesia [1]. Flats are also one strategy to optimize land use. The flats construction is intended for low-income society, therefore the flat’s operational costs must be cheap. Even though the operation is cheap, it must still provide comfort for its residents, because living comfort is a basic requirement that must be felt by everyone.

Problems that often occur in part occur in vertical housing are ventilation system problems, this problem also occurs in flats. The Ministry of Public Works and Public Housing has also formulated 10 Flats problems in Indonesia at the Indonesia Property Expo in 2018, one of the flats problems in Indonesia is the problem of the ventilation system which causes a lack of air circulation due to non-optimal layout space and lack of openings from each unit. So, the residents didn’t get sufficient natural lighting and adequate air circulation. Besides, each residential unit has an area of 24 m², which is inhabited by more than 2 people and filled with household furniture. The solution to overcome this problem is to optimize the use of natural ventilation to expediting air circulation in residential units. Air circulation has good benefits for buildings as an effort to sanitation, comfort and cooling the space if it can be channeled properly into the building [2-3]. One way to improve the air-flow into the building is...
by maximizing the natural ventilation system for air changes to the building. The extent of ventilation relates to the air volume and circulation in the building, if the size of the ventilation is too small, it will cause the air to not circulate properly [4].

The purpose of this study is to conduct a review and research related to the natural ventilation performance in the flat design at Banda Aceh and to find out how the performance of natural ventilation in the flats itself.

2. Natural ventilation

Natural ventilation is an air circulation system that exchanges the air naturally (does not involve mechanical equipment, such as fans, exhaust fans, air conditioning, and so on). Natural ventilation is needed so the air in the room remains healthy and comfortable. Natural ventilation offers healthy and comfortable air circulation without additional energy [5]. Air circulation in natural ventilation system can be occurring because there is a difference in air pressure outside and inside the building.

The performance of natural ventilation is influenced by several factors that cause air to enter the building. These factors are building’s layout and orientation, opening’s orientation, opening’s location, opening’s dimensions, opening’s type, and air-flow controller.

2.1. Building’s layout and orientation

The building’s layout in an area will affect the air movement. The location of the building which forms an angle to the direction of the coming wind will reduce wind speed by 50-60% [6]. The best building’s orientation is perpendicular to the coming wind direction.

Building’s layout and orientation also affect the air movement around the building. Air movement is formed due to differences in pressure in the air. Because of the difference pressure, the air moves and tries to balance the pressure. This pressure difference can be utilized by natural ventilation to channel air from outside into the building.

2.2. Opening’s orientation

The opening’s orientation will not only affect the air velocity, but also air-flow’s pattern in the room. The position of the inlet and outlet can be divided into three, namely face to face, side by side and on the same side, as shown in Figure 1.

2.3. Opening’s location

One of the requirements for a good natural ventilation system is an attempt to create cross ventilation. It can be done with providing openings on both sides of the room so the opportunity for air to flow in and out can be maximized. It is portrayed by Figure 2.
2.4. Opening’s dimensions
To make air circulation run properly, it is necessary to have an opening’s area with a certain value. The calculation of the minimum opening’s area in the room facade is 40% - 80% of the wall area and 20% of the floor area and for the ventilation’s area, according to the SNI Department of Public Housing the minimum of fixed ventilation’s area are 5% of the room's floor area, while the incidental ventilation area (can be opened and closed) minimum 5% of room’s floor area. That numbers are the requirement of the opening’s area so the air can circulate properly in a humid tropical climate with normal air velocity conditions (0.6 m/sec to 1.5 m/sec).

2.5. Opening’s type
The opening’s type determines the volume of air distribution at indoor space, as shown by Figure 3. Every opening’s type has a different level of effectiveness. Opening’s type plays main role in circulating air to the building. Therefore, openings should be able to function as follows:

- As an air director in the space as much as possible.
- Must be optimized to support airflow and air change.
- Must be flexible to open and close as needed.

2.6. Air-flow controller
The air-flow controller also plays a role in the use of natural ventilation system. The air-flow controller can determine the air motion, direction, and pattern in the building. Different air-flow controller’s locations and types will make different results too. The air-flow controller can be a canopy, louvers even shutters.

3. Research Method
The research method used is the observation method with descriptive surveys. The object of this research is a type 24 apartment building in Banda Aceh. A descriptive survey aims to look for symptoms using observation methods. The observation method is a method carried out by direct observation and recording of the symptoms of the phenomena under study [7]. This research begins with a field study on the flats building, then analyzes the building design and compares the existing conditions with a theoretical study. The analysis is more emphasized on the existing opening’s conditions and other design elements that influence natural ventilation performances.
4. Result and discussion

4.1. Flats building
The flats in this study are rental flats managed by the Banda Aceh City Government, located on Rama Setia, Merduati, Kuta Raja, Banda Aceh. This flat consists of 4 residential blocks named Block A, Block B, Block C and Block D. Figure 4, 5, and 6 depict the flat.

![Figure 4. Flat site plant and building's perspective.](image)

![Figure 5. 2nd to 5th floor plan.](image)

![Figure 6. Unit floor plan.](image)

This flats building has only one type of residential’s unit, namely, type 24 with 24 m² area. Type 24 residential units consist of 1 bedroom, 1 family room, 1 bathroom, and 1 clothes drying room.

4.2. Building’s layout and orientation
This building has been arranged parallel to the direction of the site (Figure 7). Buildings that are positioned like this will create some turbulence that contains small air movements and create unusual air-flow patterns. Besides, the space between buildings causes the air-flow to become narrow, which results in the building not being able to receive air movement with sufficient speed on each side (Figure 8). The parallel structure is not effective for the use of wind in humid tropical climates such as in Indonesia [6].
However, these flat’s residential units are placed in the part that is directly facing the air-flow, so that air can be accessed by residential area (Figure 9).

The building was also designed using courtyard and voids as a separator between residential unit’s rows (Figure 10 & 11). Courtyard and voids also function as a path for air circulation horizontally and vertically.
4.3. Opening’s location

Placing openings facing both sides can create a cross ventilation system, as demonstrated by Figure 12. This ventilation system is a very effective way to circulate air in the room, because cross ventilation can provide high wind speeds and the best air distribution patterns in the room [6].

![Figure 12. Cross circulation air-flows [6].](image)

Each residential unit has been designed by optimizing cross ventilation system, but the location of the inlet and outlet of the wind does not face frontally, therefore the wind does not move directly towards the outlet and results in non-optimal airflow. If air enters the unit through the hallway, the air that entering the bedroom can only be streamed through ventilation above the door and door if they are open. These can be viewed in Figure 13, 14, and 15.

![Figure 13. Indoor air circulation pattern.](image)

![Figure 14. Bedroom door and ventilation.](image)

The inlet ventilation position has the same elevation as the outlet, while the inlet coming from the window has a different elevation to allow a cross ventilation system to occur.
4.4. Opening’s dimensions
In this type 24 flats have 4 openings that affect air circulation for the residential unit, as displayed in Figure 16.

![Figure 15. Cross ventilation.](image)

![Figure 16. Opening types.](image)

The opening dimensions found in this apartment do not meet the specified requirements. From the calculation of the minimum opening area based on the floor area (20% of the floor area) the opening area does not meet the requirements. The opening area that should be available is 4.80 m$^2$ while only 4.58 m$^2$ is available. When reviewed based on the front and rear façade wall area (40-80%) the opening area does not meet the minimum requirement of 40%, the opening area that should be available on the façade side of the residential unit is 5.04 m$^2$ while only 2.84 m$^2$ is available, as well as the rear side of the residential unit only available 1.74 m$^2$. If reviewed based on SNI the Department of Public Housing, the fixed ventilation remains not available at all in the residential units, except for the bathroom. As for incidental ventilation requirements, ventilation in these flats meets a minimum standard of 5%. It is summarized in Table 1.

| Building’s Part        | Area  | Standard | Existing condition | note               |
|------------------------|-------|----------|--------------------|--------------------|
| Floor area             | 24 m$^2$ | 20%     | 4.80               | 4.58               | Does not meet standards |
| Façade area            | 12.6 m$^2$ | 40%     | 5.04               | 2.84               | Does not meet standards |
| Rear wall area         | 12.6 m$^2$ | 40%     | 5.04               | 1.74               | Does not meet standards |
| Fixed Ventilation      | 24 m$^2$ | 5%       | 1.20               | 0                  | Does not meet standards |
| Incidental Ventilation | 24 m$^2$ | 5%       | 1.20               | 4.58               | Meet the standards      |

Table 1. Opening’s area analysis.
4.5. Openings type
Air openings available in this flats building are dominated by awning opening type, awning opening has the ability to steamed air effectively by 75% [9]. This opening type is one type of openings that is effective for entering air into the room, as Figure 17 and 18 reveals. However, the air volume that circulates in the building also affected by wind speed and temperature.

![Figure 17. Opening's effectiveness][8]

![Figure 18. Openings type.][9]

4.6. Air-flow controller
In this flat’s design uses a lot of design elements that has a function to control the air-flow to enter the residential unit.

![Figure 19. Rear side of flats.][10]

The columns are in the flats prominent than the walls used for rooms. This can direct the flow of air into the bedroom, this also applies to the walls of the laundry room and the canopy which is located above the bedroom opening (Figure 19).
The principle of directing the air-flow is also used on the inside of the flats building. The columns in the hallway area are also designed to be more prominent than the walls from the residential units (Figure 20). In the hallway there are lattices and parapet walls that function as air-flow controllers.

The left and right-side view of the building only uses an iron railing and does not use the walls as a barrier, as seen in Figure 21. This can steam the air optimally because there is no air-flow barrier.

5. Conclusions

Based on the results of field analysis and theoretical studies on the object of this study, it can be seen that the shape of the flats is designed to be able to maximize natural ventilation. This can be seen from:

- Layout and orientation of the buildings arranged as possible to maximize the air movement into the residential unit
- Every residential unit designed using a cross ventilation system that can maximize air circulation
- Every residential unit uses an effective opening type, which is awning type which can effective circulating air by 75%
- There is an air-flow controller concept like column location, wall and canopy that can direct the air-flow to the residential unit

However, the maximum air movement cannot be felt by the occupants of the residential units due to the opening’s dimensions which do not meet the standard 20% of the floor area, 40% of the wall area and also do not meet the SNI requirements for Public Housing to provide for fixed ventilation.
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