The roof ventilation as Alternative Passive Cooling for high density building in the Humid Tropics

Sukawi[*], Agung Dwiyanto[**], Suzanna Ratih Sari[**]

[*] Study Program of D3 Architectural Design, Faculty of Engineering, Diponegoro University Semarang, Indonesia
[**] Department of Architecture, Faculty of Engineering, Diponegoro University Semarang, Indonesia

Abstract- The need for building decent and affordable housing for the middle to lower is increasing. Housing design done by the developers often have a uniform design of the design especially interms of building shape, building area and site area. Due to land limitation, it now appears that residential buildings are built with series model, so that they only have one facade. This is due to the neighborhood buildings are attached to the wall of our building either right, left or rear side.The use of roof ventilation in buildings is one way to improve the natural ventilation in addition to cross ventilation. One of the factors considered in the context of energy efficient is the use of climate such as solar and wind. This study emphasizes in the utilization of wind for natural ventilation, and the aim is to reveal the qualities of simple natural ventilation in high density environments. Building density is one of the factors that affect the principle of micro-climatic conditions in the room. With the density and shape of residential buildings that have only one facade, it needs tactics to be able to take advantage of climatic conditions and shape of the roof in residential buildings. This research is also addressed to identify and analyze the performance of natural ventilation with simple roofs ventilation in a neighborhood with high density. This study was conducted by comparing several roof models with ventilation that found in the study area by applying a ventilation stack. This comparison is to know how effective the roof ventilation design that can increase the effectiveness of roof ventilation design that can improve the air movement inside residential buildings in high density environments.

Index Terms- Roof ventilation, air movement, high density building, tropical architecture

I. INTRODUCTION

Tropical climate conditions in the research area have some characteristics such as: high air temperatures, high relative humidity and low wind speeds that make the environment uncomfortable. The tendency of the problems encountered in the humid tropics is the sign that the magnitude of the heat load in the building influence the formation of the air temperature in the room. The existancy of building roof is also useful to serve the health into the building. Diversity of roof forms ranging from the traditional and modern that able to influence the heat conditions in the building. The roof forms of Java housing has a great influence in creating the conditioning room. Space under the roof can be a cushion of hot air to be discharged out of the building. (Samodra 2005 & Purwanto, 2006)

Roof ventilation design planning to support the concept of upward air flow will be managed to create a good thermal comfort inside the building if all planning aspects have been considered and taken into account. It is important to do because of the failure of the roof ventilation design will likely have the opposite effect, which adds to the discomfort of the room due to heat. According to Egan (1999) and Aynsley (1977), natural ventilation system of the building can be divided into two kinds, those are: ventilation with style thermal / chimney (stack effect); and ventilation with wind force / pressure wind / cross (cross ventilation). Style thermal vents can occur when there is a temperature difference between the outside air (exterior) and inside air (interior), then the pressure difference caused by differences of air distribution can be used to get ventilation andall depending on the temperature difference inside and outside building, as well as the difference height of ventilation holes (inlet and outlet).

Szokolay (2004) and Santamouris (1997), describes a method for optimal passive cooling humid tropical climate is the effect of wind movement, namely physiological cooling not only depend on the wind speed but also the activity and clothing used by humans. In the passive cooling method can expand the comfort zone that is felt by humans. One type of natural ventilation is the stack effect. Based on Santoso H (2007), he explained that the air movement created by the stack effect is usually not sufficient to achieve a physiological cooling, because it is less than the recommended airspeed to cool down the air from 0.15 to 1.5 m / s especially during tropical climates.

One way passive cooling method for the tropical climate is a ventilation stack strategy. Stack ventilation caused by stack pressure or buoyancy in an opening related to the variation of water density as a result of the temperature difference between the opposite openings. The same principle can be used openings at different heights, in which the pressure difference between the two openings are related to the vertical gradient (Awbi, 2004). Stack effect is a result of the reduced air density when there is an increase in temperature. The greater the temperature difference between the two air-related, the greater the buoyancy temperature, buoyancy difference is the driving force behind the circulation of the stack effect, depending on the temperature difference and the difference in height. Comparatively hot air inside the building rose to escape through the openings at the top, is replaced by cooler outside air coming in through the openings on the bottom around the circumference of the building. (Croome, 2003; Roulet,2008 and Allard F,2005).

According Santosa (2000), the shape of the building roof must have good air circulation. Roofs that do not have air circulation will deliver heat in air trapped inside the roof and further influence the heat conditions in the space below. The use of modern roof materials in a very tight potition will have no space for air to flow so that the roof can not "breathe" and theheat that occurs on top surface of the roof will affect the thermal conditions in the space under the roof. For the design of the roof is good to have good circulation system so that hot air will not be trapped in the roof cavity. Research done by Febrita (2011) and Pranoto (2007) explain that natural ventilation system in the humid tropics has the goal of removing a number of heat inside the buildings produced by solar radiation and heat recovery from the inside users (such as human and equipment). Wind speed that can provide thermal comfort at a temperature of around 32^{o}C, amounting to 0.6 m / sec. One of the requirement to achieve thermal comfort, the square meter of opening preferably 40% of the total wall. More than that will not optimal (Sukawi,2010;2013).

II. RESEARCH METHODOLOGY

Research methods used in this study is observation method with a descriptive survey. The object of research is residential buildings that have high density and is arranged in a simple developement. Descriptive survey is aimed to explore the phenomenon / symptom by observation. Observation method is a method done by direct observation, measurement and recording of symptoms or a phenomenon. (Arikunto, 1998).

The method in this research is observation, recording of measurement within and outside the home with tools such as a thermometer (for measuring the temperature of outdoor and indoor), hygrometer (to measure humidity), hot wire anemometer (to measure air movement both within indoor and outdoor). The determination of measurement points that located in the house is carried out on the living room or family room or kitchen and dining room located at the back of the layout of the house. While the outdoor measurements carried out on the patio and the street in front of the residence. The collection of primary data obtained in the field, will be cross check with secondary data such as temperature, humidity and wind movement from BMKG to look at macro climatic conditions and the urban environment. This research was carried out during the dry season in August 2015.

This study takes an example in housing units built by the government, namely Bukit Sendang Mulyo Housing. The residential complex is located in the southern city of Semarang, designed by the developers around 1995 within Tembalang district. Originally, Tembalabg ditrisct is a hilly area transformed into housing for lower middle income people with affordable prices. Along with population growth, the demand for housing has increased. The hills in the area was gradually taken over by developer to be used as residential land.

III. RESULT AND DISCUSSION

The development of Perum Bukit Sendang Mulyo planned for a small family who recently married and needed somewhere to stay close to Semarang city and at affordable prices for families whose income is mediocre and work within the scope of Semarang as a small city (hinterland). Types of houses offered in Bukit Sendang Mulyo is quite varied. Generally the type of row houses are small type: type 36/84. In the development of row housing, because of the space requirements, many of them are utilized the backyard to became a space. Several housing units developed room at the back side of housing which is equipped by roof openings to get the lighting and ventilation.

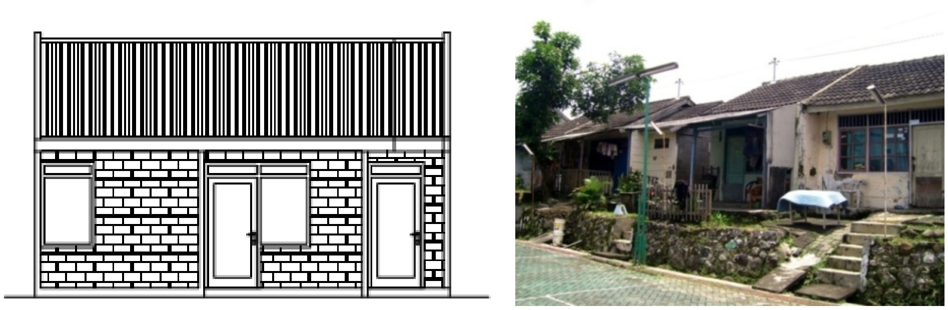


Figure 1. Front Fasade House

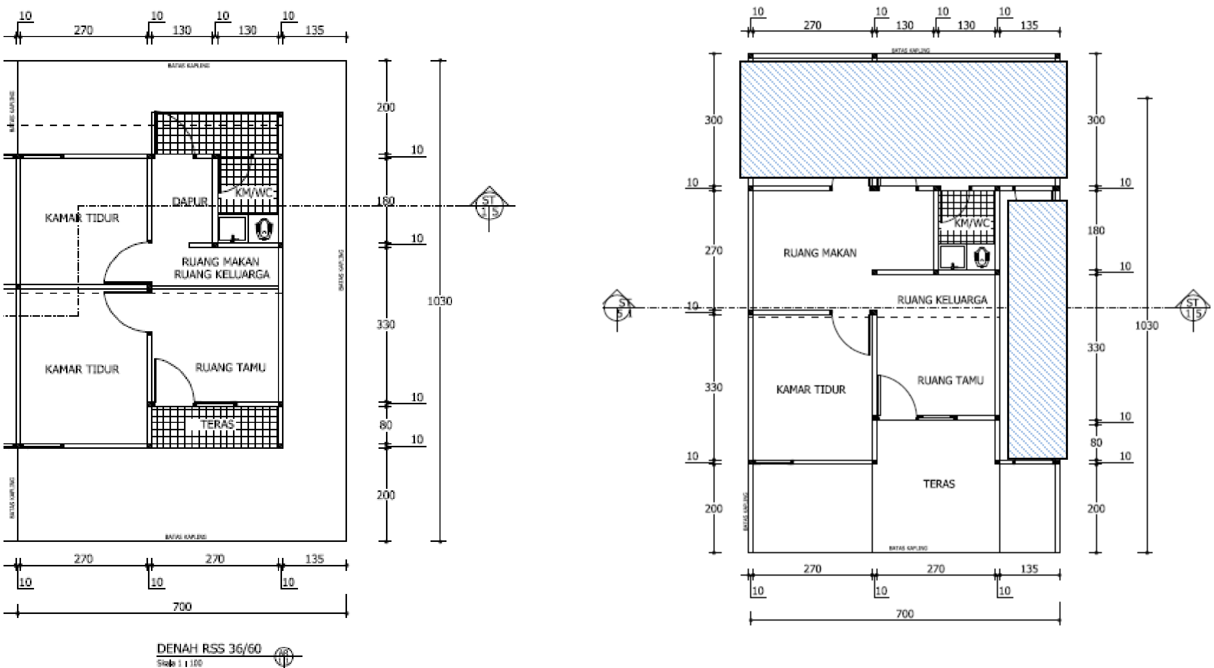
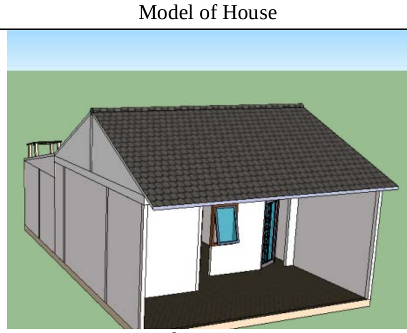
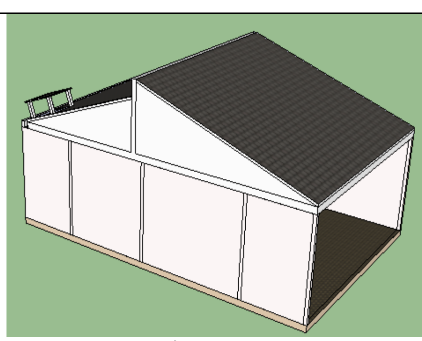
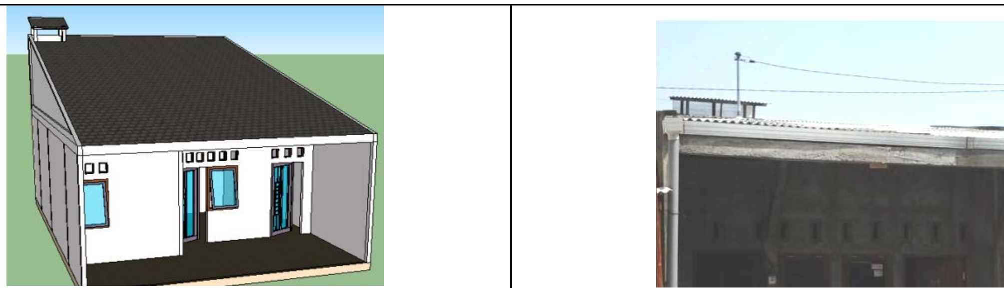


Figure 2. Plan early and plan the development of House RS type 36/84

In the development of residential development, most of them are on the back of the house so the site leaving only the front section. As a result, by simply openings on one side of the house (on the front façade), this study tries to explore the potential roof openings at the back side of the house. To determine the influence of roof ventilation, by comparing the shelter that has a wide roof openings with a size of 2x2 m with a shelter that does not have a roof opening only exploit loopholes in precarious and asbestos in flowing the air out of the building.

Model of House	The Opening roof shape
 Budiono House	
 Ana House	



Siswanto House

Figure 3. The research house has a roof openings with different roof models

This research was conducted by observing and analyzing multiple occupancy have roof openings. 3 samples of housing units both have roof vents with models of different roof shapes, turns out to have a response to environments with different temperatures.

A. Temperature

Boediono House has the highest temperature conditions among the two homes, while Ana house and Siswanto house have lower temperatures. Meanwhile, the Siswanto house having the lowest temperature conditions compared to 3 houses studied. The temperature in the space below the roof openings have the highest temperature of 35.8^{o} C, while at Siswanto house occurred during the day 13.00. While at Ana house and Siswanto house, the highest temperature in the space under the roof opening is 34.5^{o} C. So there is a difference in temperature which shown 1.3^{o} C. The difference of this magnitude can be influenced by the shape of the roof and roof height. From the survey it is known that the Boediono house high roof openings have a height of 2.5 meter from the floor. Meanwhile, Ana house has a roof openings as high as 3.45 meter on the floor and the house has openings Siswanto house high roof 5.5 meter from the floor**.**

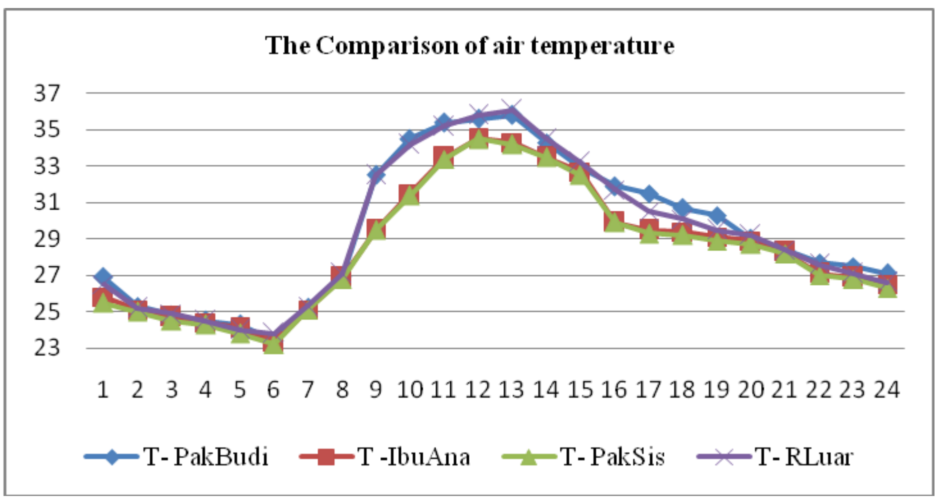


Figure 4. The comparison of air temperature at the rear of the house (kitchen)

The temperature difference in the back room (kitchen) is also influenced by the roofing material. Home Mr. Boediono has the highest temperature during the day 13.00 at 35.8^{o} C because the material used is asbestos roof and the height of the roof which has openings sufficiently low at 2.5 m. While the material Ana House roof made of tiles and have a height of 3.45 meter on the roof openings so as to reduce the environmental temperature, which reached 36.1^{o} C. For Siswanto House, although roofing materials made of asbestos, but have a roof aperture height 5.5 meter from the floor, so that able to lower the temperature becomes 34.5^{o} C.

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B. Air Movement

The house has 3 models of roof ventilation with different roof shapes as shown in the following figure:

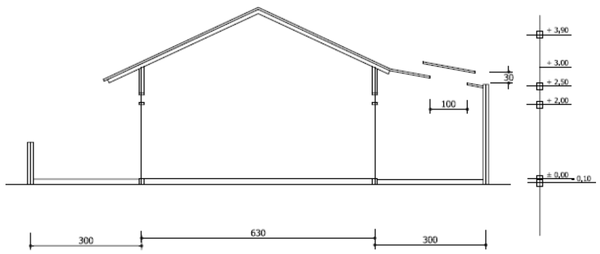
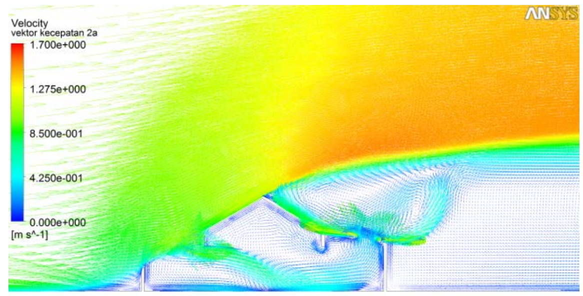
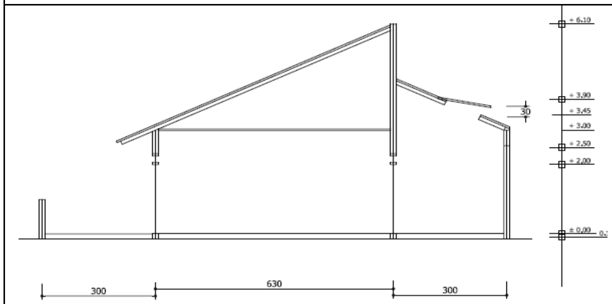
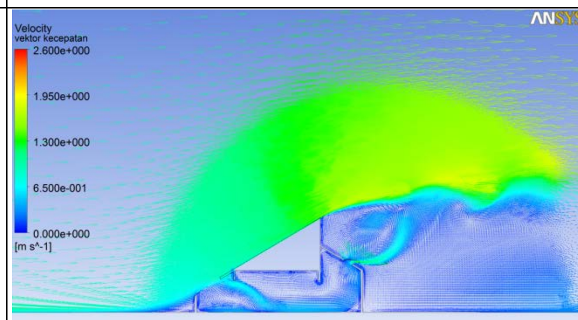
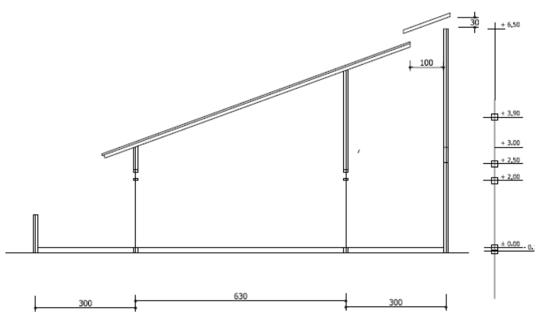
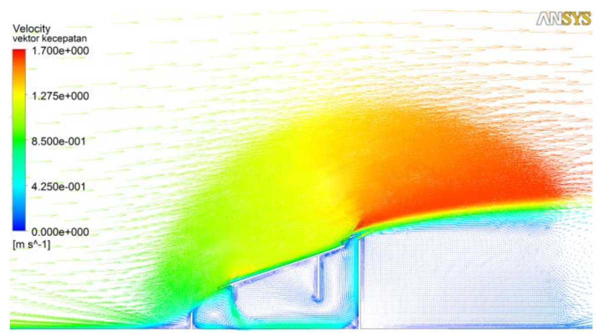
<table>
<tr><th>House Section</th><th>Simulation</th></tr>
<tr><td>
Budiono House</td><td></td></tr>
<tr><td>
Ana House</td><td></td></tr>
<tr><td>
Siswanto House</td><td></td></tr>
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Figure 5. The pattern of air movement at home and the results of simulation at a wind speed of 1 m / s

From the movement patterns of 3 houses units above, it can be seen that the height of the roof give effect toward the density of the air flow movement. Home that has the highest roof is Siswanto House, on the back side of the house , it can get the most optimal air movement compared to the other house. Based on the results of measurements in the field, if air movement outside the range 1.0 - 1.3 m / s, the air movement in the back room (kitchen) ranging from 0.11 - 0.12 m / sec. This can happen with a note, the door remains open. So that the optimum air movement will happen if during the day with the door left open. If the door is closed at night, the air movement is in the back room (kitchen) ranging from 0.02 - 0.05 m / sec.

CFD simulation results with fluent software, the results obtained are consistent with the results of field measurements from the 3 houses, most major air movement in the back room (kitchen) is the Siswanto house. Higher air movement is caused by a roof ventilation openings which can drain the hot air out of the building. The higher the position of the roof ventilation, the greater the air movement occurs.

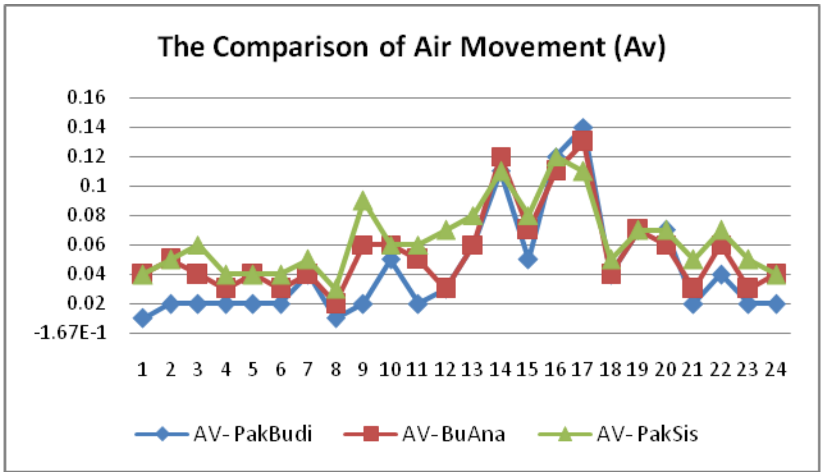

Figure 6. The comparison of air movement at the rear of the house (kitchen)

This study proves that a hole in the roof space is effective to create an air flow at a high outlet moved by the buoyancy, and affects the colder air to replace the hot air that comes out. This is consistent with Bernouli about the effect on heat transfer, so that the air movement will cause movement of air from cold air into hot air. The hot air will rise upwards resulting a smooth movement of air circulation in housing units that was utilized the roof openings. The cooling effect is also influenced by the wind speed that can improve the the quality of comfort inside the room. This could be a solution for a solid housing that has only one facade because the other side of the building facade bordering the neighboring walls.

IV. CONCLUSION

Results of this research is to know the performance of natural ventilation with potential openings that lined with the roof of residential building in order to get around natural ventilation for thermal comfort in the buildings. Houses with higher roof openings have a lower temperature and air movement are higher inside rather than a house with a roof opening with a position lower than the floor surface. The ideal of roof openings is located at higher roof and in the back room of the house. This proves that the design elements of roof openings have contributed in creating and influencing conditions of temperature and air movement in the room. A space created by opening the roof can make flowing air at high outlet by the buoyancy, so it pushes the hot air to exit the building.

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AUTHORS

First Author – Sukawi, Lecturer, Program of D3 Architectural Design, Faculty of Engineering, Diponegoro University Semarang, Indonesia, zukawi@gmail.com.
Second Author – Agung Dwiyanto, Lecturer, Department of Architecture, Faculty of Engineering, Diponegoro University Semarang, Indonesia, agungdwie@gmail.com.
Third Author – Suzanna Ratih Sari, Doctor, Department of Architecture, Faculty of Engineering, Diponegoro University Semarang, Indonesia,ratihsaris@yahoo.com.

Correspondence Author – Sukawi, zukawi@gmail.com, sukawi@live.undip.ac.id, +628122817739.