Enhance Hybrid Ventilation Through Stack Ventilation Strategies Using Roof Solar Collector Combined With Turbine Ventilator In Tropical Humid Climate

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Abstract

Many architects and building designers preferred to choose natural cross ventilation to generate indoor air movement and improve thermal comfort in their building. Unfortunately, in the certain conditions, especially in hot climate, the application of conventional concept of natural ventilation alone does not always successfully. These circumstances could be provided an effective outlet area at the top of building and use a stack ventilation strategy for the best solutions. This research tend to investigate and develop a new stack ventilation strategy using the solar roof collector combine with turbine ventilator on building model under Indonesian conditions. The objectives of this research are to develop the best feature of hybrid system and to create a new type of ventilation system to achieve indoor thermal comfort. There are three methodologies used for this research namely, theoretical background, design development prototype and computational fluid dynamics (CFD) simulation. This research will design and create the model of hybrid ventilation to carry out the simulations. Finally, the performance of this new hybrid ventilation system will be studied in modeling building using CFD simulations to determine temperature difference and air velocity. The outcome of the study is expected that the development of the new hybrid ventilation through stack ventilation strategy using roof solar ventilator combine with hybrid turbine ventilator can significantly reduce air temperature in tropical humid climate. The study also expects that appropriate design decisions on this strategy will not only be an energy efficient tool to improve indoor thermal environment but also it will enhance the building aesthetic.

Key words : Hybrid Ventilation, Stack Ventilation, Roof Solar Collector, Turbine Ventilator, CFD

1. Introduction

Hot humid tropical conditions in Indonesia affect the high temperature and low air flow which affect on the comfortable indoor environment. Enhancement of stack ventilation strategy with hybrid ventilation system expected not only can significantly decrease air temperature in the rooms but also the large energy savings can be achieved. Furthermore, it can reduce the reliance on air conditioning, saving energy, cost effective and consequential environmental effects of full year-round air conditioning.

1.1 Problem Statement

Other specific problem statements of this study are as follows:

1. There are some problem and potential in hybrid ventilation system through stack ventilation strategy using roof solar collector combine with turbine ventilator. Therefore, developing of the best hybrid ventilation system will be needed.
2. There is a lack of examine of new hybrid ventilation system through stack ventilation strategy using roof solar collector combine with turbine ventilator.

1.2 Research Objective

This research tend to investigate and develop a new hybrid ventilation through stack ventilation strategy using the solar roof collector combine with turbine ventilator on building model under

Indonesian conditions. The objectives of this research are to develop the best feature of hybrid system and to create a new type of ventilation system to achieve indoor thermal comfort.

1.3 Literature Review

Hybrid ventilation is a new ventilation concept that combines between natural and mechanical systems with best features. In order to characterize a hybrid ventilation strategy, it is important to describe the hybrid ventilation principle. The main hybrid ventilation principles are firstly is natural and mechanical ventilation, this principle is based on two fully autonomous systems where the control strategy either switches between the two systems, or uses one system for some tasks and the other system for other tasks. Secondly, fan-assisted natural ventilation, this principle is based on a natural ventilation system combined with an extract of supply fan. Thirdly, stack and wind-supported mechanical ventilation, this principle is based on a mechanical ventilation system that makes optimal use of natural driving forces. [1].

Meanwhile, according to Randall (2006) the natural driving forces for ventilation are the wind and stack effect. These are, of course, variable and less easy to control than the forces associated with mechanical systems. On the other hand, where used successfully they can enormously reduce capital and running costs of mechanical and electrical plant and reduce the need for plant space [2]. Moreover, Gladyszeska et.al (2012) stated that the stack ventilation is driven by difference between outdoor and indoor air density which are caused by thermal discrepancy. However, the direction and velocity of the wind have an important effect on it. In the most favorable situation, when a light wind blow in such way that the exhausted air is sucked out at the outlets of ventilation ducts, simultaneously fresh air flows through air inlet vents inside the rooms, which increases the air change rate [3]. Ismail et.al (2012) stated that stack ventilation can be defined as the upward movement of air through openings in a building fabric due to thermal buoyancy and/or negative pressure generated by the wind over the roof. This principle makes this ventilation strategy less dependent on outdoor wind condition and makes it more significant to improve natural ventilation in a building with limited side openings, like in a terrace house [4].

On the other hand, solar induced ventilation is able to reduce indoor air temperature by roof solar collector strategy. According to Awbi, (2003), the advantage of a roof collector is that a large surface area is available for collecting the solar energy. Hence, depending on its design and the climate, higher air exit temperatures can be achieve ventilation rates close to a solar chimney [5]. However, Khedari et al,(2000) stated that the solar induced ventilation through roof solar collector strategy alone is not sufficient to achieve comfort for occupants. The required Air Change per hour (ACH) for comfort was up 20 ACH but by using roof solar collector the ACH rate only 4-5 ACH. Based on literature survey, it can be summarized that the potential solar induced ventilation using stack ventilation strategy alone need to improve in order to enhance the performance and stability [6]. In addition, according to Fatimah, et al (2012) the purpose of the roof solar collector is to capture maximum amount of solar radiation in order to heat up the air. The function of the roof solar collector is to maximize the air temperature in the channel. Therefore, the most important configuration variables are the channel, cavity width, inlet size and tilt angle. Inside the channel, the cavity width and the channel length influence the creation of the thermal and velocity boundary layers [7].

Furthermore, nowadays, saving energy, utilizing natural and green energy resources are one of the key concerns. By employing natural methods, ventilation energy can be saved to replace electric fans or air conditioners. Wind driven turbine ventilator is the one of natural ventilation devices [8]. However, the research of turbine ventilator is still limited. It has to develop further to achieve good performance and it can also have good function to achieve indoor thermal comfort for occupants. According to Lai, (2003) turbine ventilator is an equipment that use natural wind forces to bring out the rotation of the turbine and creates a negative pressure at the down–stream end of the pipe line to exhaust airflow [9]. In addition, Lin,Y.P. et.al, (2010) stated that turbine ventilator is a helpful part of a building's ventilation system [10]. Wind-driven turbine ventilator is one of the ventilation strategies that is considerable cheap and technologically simple to operate [11]. Daut et.al (2011) stated that the main function of the free spinning turbine/roof ventilator is to provide fresh air in roof space and living area. In addition, in certain condition turbine ventilator can produce the electrical energy from the roof ventilator that will spin when the wind exist [12]. However, Feng et al, (2011) stated that the performance of turbine ventilator always unstable and depends on the outdoor wind condition [13].

In addition, according to M. C. Hsieh, et.al (2013) there are two rotating principles of the turbine ventilator. The first principle is the hydromechanics that the air current can flow from the high temperature area to the low temperature area to motivate blades to rotate. This air convector can both exhaust and ventilate spontaneously, when the indoor and outdoor temperature is different. The air can flow through the gap of the turbine blades from high temperature side to low temperature side; therefore a spontaneous ventilating phenomenon is formed. The second principle, when the turbine wheel revolves, the high temperature air will be discharged from the room, so the air density in the room can be reduced, then the cold air outdoor enters the room to achieve the convection goal [14].
According to Frank, et.al (2007), hybrid ventilation is the combination of natural and mechanical ventilation, is an encouraging strategy to achieve energy efficient with good indoor air quality and thermal comfort [15]. Fanger (1970) stated that thermal comfort for a person is defined that condition of mind which expresses satisfaction with the thermal environment. The reason for creating thermal comfort is to satisfy man's desire to feel thermally comfortable. The most important variables which influence the condition of thermal comfort are activity level (heat production in the body), thermal resistance of the clothing (clo-value), air temperature, meant radiant temperature, relative air velocity and water vapour pressure in ambient air [16]. Another statement discussed by Allard (1998) that human thermal comfort is defined as the conditions in which a person would prefer neither warmer nor cooler surroundings [17]. The statement also supported by Santamouris (2003) thermal comfort is listed by occupant that is one of more important requirement for any building. The occupants will react to any discomfort and then take actions to restore the condition. Therefore, the successful building is depends on comfortable indoor environment. On the other hand, thermal comfort is governed by many physiological mechanisms of the body. Human body have different perception from person to person so that it is difficult to get more than 50 % of the people affected to agree that the conditions are comfortable [18].
Base on the fact mentioned above, there is no research attempt to combine those strategies to enhance the performance and stability. For that reason, it is suggested in the present research to develop a potential of new hybrid ventilation system through stack ventilation strategy using roof solar collector combine with turbine ventilator. Further, the experimentally test will be conducted to examine their performance.

2. Methodology

2.1.Theoretical Method & Inventory

a. Literature review to collect all the relevant information about :
   - hybrid ventilation
   - stack ventilation
   - roof solar collector
   - turbine ventilator
   - thermal comfort

b.The information will be taken from journals, papers, books, standards, website and interviewing with the expert.

2.2 Computer Simulation Method

This simulation is to test and validate the model of new hybrid ventilation system and then to identified and determined the performance of the model. The processes are as follows :

a. Development of simulation modeling for the base case.
b. Test the base case and compare with the real data for validation purposes.
c. Applied the new hybrid ventilation system to the base model and analyzed the indoor are condition or the test model for example the air velocity, ambient air temperature, solar radiation etc.

3. Discussion

3.1 Development Prototype

The prototype models investigated in the experiment. Prototype is the base model, its means that its configuration, dimensions, and material are derived from literature study.

The configurations and dimensions of the prototype are resulted from literature survey. The effective length of roof solar collector's channel is 1 m. (Khedari et.al 1997).Therefore the overall dimensions of roof solar collector are 1 x 1 x 0.2 m (length, width, cavity width)(Fatimah, et.al, 2012)
The effective solar collector tilt angle is 30°, inclined from horizontal. The cavity width of 0.2 m is selected as smaller size, such as 0.1 m, (Bouchair, 1994, Miyazaki, 2006). This prototype has high air temperature at the exit of roof solar collector is essential in achieving high air temperature inside the vertical stack. The maximum height of vertical overall height is 1 m for prototype C. Meanwhile, the height of vertical stack of prototype A and B are similar 0.5 m.
The present research, the structure of the prototype is made of mild steel or stainless steel. The outer and inner sides of the walls were covers with aluminium foil. The purpose of cover by aluminium foil at the outer of the wall is to reduce the solar radiation absorption, whereas at the inner inside, it reduces the radiative heat transfer between the walls. The aluminium foil was painted with black epoxy paint in order to enhance the solar radiation absorption (Fatimah, 2012). The rock wool insulation underneath the absorber is able to reduce heat transfer to the space below. The space beneath the prototype was fully covered in reducing wind effect at that roof solar collector inlet.

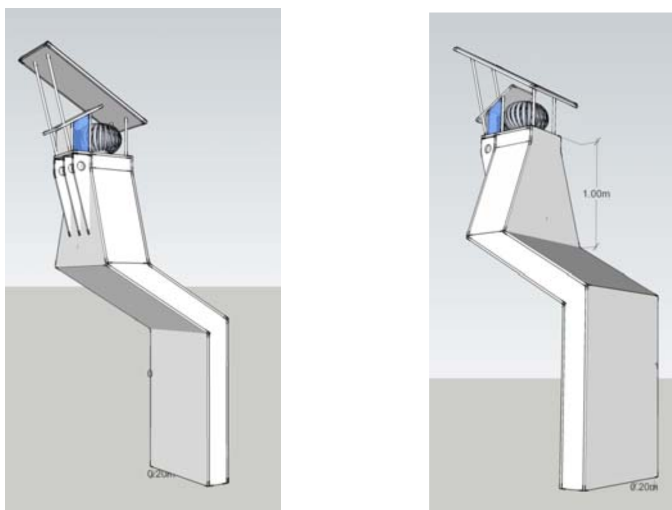

Figure. 1. The Prototype

3.2 Component of prototype

There are four components in this model of present research:

- First component is Roof Solar Collector. (RSC)
- Second component is vertical stack
- Third component is conventional turbine ventilator
- Fourth component is exhaust fan generated by photovoltaic solar panel to support turbine ventilator.

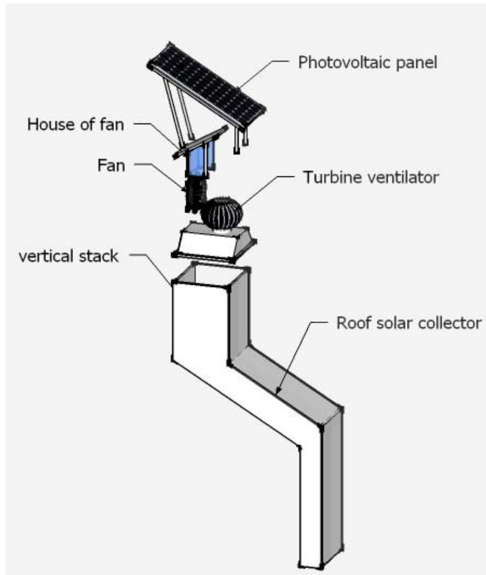

Figure. 2. Components of the Prototype

3.3 Basic Concept & Prototype Mechanism

The system of this prototype will utilize natural power. The mechanism of this prototype are :

- If the indoor temperature increase, the indoor hot air will be raise up and exit through air channel in the indoor ceilings and flow through the channel on the roof.
- Roof solar collector will raised the air temperature in the channel when the solar collector is heated by sunlight, the heated air in the channel rises then flows into the vertical stack due to the pressure difference.
- At the top, the turbine ventilator generated by photovoltaic can suck the heated air move to outside of the building. The turbine ventilator can spin all year round 24 hours a day so that the hot air from indoor room always remove all the time.
- With this new strategy, the presence or absence of wind, the turbine ventilators will keep spinning because of fan supported by photovoltaic power.
- Hopefully, this new combination strategy can be made as an alternative device to reduce indoor air temperature to achieve thermal comfort.

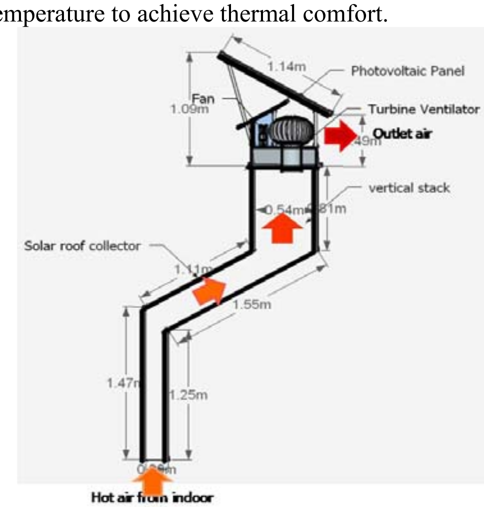

Figure. 3. Basic concept and Prototype Mechanism

Figure. 4. Application Prototype of hybrid turbine ventilator with roof solar collector

4 Conclusion

The outcome of the study is expected to show that, the effectiveness of the new hybrid ventilation through stack ventilation strategy using roof solar collector combine with turbine ventilator systems will decrease air temperature to achieve indoor thermal comfort. The study also expect to suggest that appropriate design decisions on stack ventilation through roof solar ventilator strategy combine with turbine ventilator systems can significantly reduce the heat on building in hot humid climate.

The most important aspect is the thermal environment and energy efficiency. Hence, findings of this study will enable and provide architects and building designers with wider range of options in selecting appropriate hybrid ventilation design strategy for achieving the balance between thermal environment and energy consumption. In the coming future, from the architectural point of view, it is quite interesting to expect that the turbine ventilator combine with solar roof collector will not only be an energy efficient tool to improve indoor thermal environment but also it will enhance the building aesthetic.

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