

## **POSSIBILITY TO USE SOLAR INDUCED VENTILATION STRATEGIES IN TROPICAL CONDITIONS BY COMPUTATIONAL FLUID DYNAMIC SIMULATION**

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### **Abstract**

The climatic conditions of the tropical regions are characterized by high air temperatures, high relative humidity's and very low wind speeds, which make the environmental conditions uncomfortable. The use of solar roof chimneys in buildings is one way to increase natural ventilation and, as a consequence, improve indoor air quality. The present study evaluates the stack induced ventilation strategies performance on experimental room model in Malaysian condition. The use of solar induced ventilation strategies in building was investigated using CFD FloVent technique. Validation of CFD Flovent was done by comparing the pilot testing. The effect of solar chimney, solar wall, and solar roof were simulated in order to determine the best option for a tropical ventilation strategy. The simulations were performed on selected model of trombe wall, solar chimney, and solar roof. The results showed the solar chimney can increase air velocity in the room but also increase heat gain in the room. The results also indicated that solar roof reduced the heat gain but resulted in low air velocity. Use of solar wall can increase air velocity in the room depending on the orientation of the solar wall. Based on the above finding a combined strategy was developed to increase stack induced ventilation.

Key word : Solar induced ventilation, Solar Chimney, Solar Roof, Trombe Wall

### **A. INTRODUCTION**

In tropical climatic regions passive cooling is one of the most difficult problems to solve. The simplest and the most effective solution for active cooling is to introduce air conditioning. However, such equipment involves high initial and operational costs for installation, energy and maintenance. Therefore air conditioners are unlikely to be applied widely, in particular, for residential building. Thus, a passive cooling system is more desirable. Although in Malaysia, passive cooling method is a popular cooling strategy adopted in residential building, researches (Pan, 1997; Tan, 1997; Jones, 1993; Zulkifli, 1991; Hui, 1998; Abdul Razak, 2004) have shown that its natural ventilation performance could not provide internal thermal comfort. Climate conscious design in the equatorial tropic assumes that air movement is one of the main cure for thermal comfort ills. According to Hui (1998), the indoor air velocity in low rise building range between 0.04m/s – 0.47 m/s. The reasons may be due to inappropriate design solutions for indoor air movement or low

outdoor air velocity remains to be determined. However, recent data from the Malaysian Meteorological Service Department showed that mean outdoor air velocity is between 1 m/s to 1.5 m/s.

In theory, there are two natural ventilation mechanisms (ASHRAE, 1997). First is by wind pressure and the second is by temperature difference or stack effect. Both mechanisms have the same aim, which is to act as an aid to create air movement and consequently control the indoor air temperature (Abdul Razak, 2004). Natural ventilation may result from air penetration through a variety of unintentional openings in the building envelope, but it also occurs as a result of manual control of building's openings doors and windows. Air is driven in and out of the building as a result of pressure differences across the openings, which are due to combined action of wind and buoyancy-driven forces. Today, natural ventilation is not only regarded as a simple measure to provide fresh air for the occupants, necessary to maintain acceptable air-quality levels, but also as an excellent energy-saving way to reduce the internal cooling load of housing located in the tropics. Depending on ambient conditions, natural ventilation may lead to indoor thermal comfort without mechanical cooling being required.

## **B. NATURAL STACK VENTILATION**

One of the more promising passive cooling methods for tropical climatic regions is the stack ventilation strategies. Stack ventilation is caused by stack pressure or buoyancy at an opening due to variation in air density as a result of different in temperature across the opening. The same principle can be applied for opening at different height, the different in pressure between them is due to the vertical gradient (Awbi,2004). It utilizes solar radiation, which is abundant in these regions, to generate the buoyant flow. However, as currently applied, the induced air movement is insufficient to create physiological cooling. More studies are needed to improve the ventilation performance of this cooling method. Velocities associated with natural convection are relatively small, usually not more than 2 m/s (Mills, 1992).

Stack induced ventilation can be improve by solar induced ventilation. However, in cases where the wind effect is not well captured then solar-induced ventilation may be a viable alternative. This strategy relies upon the heating of the building fabric by solar radiation resulting into a greater temperature difference. There are three building element commonly and used for this purpose : Trombe Wall, Solar Chimney, and Solar roof (Awbi,2004).

The first type incorporates glazed element in the wall to absorb solar irradiation into the wall structure. This building has double walls which are combined into a shaft at their upper end. The south facing shaft wall was made from glass. The solar radiation that penetrates the glass heats the inner wall. Eventually, this inner wall heats the air which will rise and induce a flow of fresh air from the openings below (Watson, 1979). Two examples of stack induced ventilation concepts is solar collector and stack height. The former shows one way to amplify stack effect by utilizing solar collectors and increasing the height of the hot air column (stack height). Critical parameters of this design are the stack height and cross sectional area of its inlet and outlet. A massive and high version of this type is needed to generate indoor air velocity as high as 1.0 to 2.0 m/s, which can be achieved easily in an ordinary shallow buildings (with no obstruction at all).

The second, form is the solar chimney which has long been known, and applied in vernacular architectural designs. In general, the induced air movement is

not used directly to suck indoor air. Instead, it is used for ventilating the building (such as in the double skin building). A stack chimney is usually designed in combination with a wind tower in hot arid climatic regions. In many types of ventilated building, winds are considered to be more important than buoyancy. This is because wind induced ventilation flow is commonly stronger than stack induced flow, in particular, in low rise buildings. A milk house that was built in 1800s is a historical example of a stack chimney application (Satwiko, 1993).

Other method is used in areas with large solar altitude. In this case a large sloping roof is used effectively to collect the solar energy (Awbi, 2004). Another solar roof design called *the Nigerian Solar Roof* was studied by Barozzi et. al., using physical and numerical (Computational Fluid Dynamics Codes) modeling and data from Ife, Nigeria. Two findings were noticeable from this experiment. Firstly, both physical and numerical experiments gave almost identical results. Thus, it showed the potential of CFD Codes to simulate air flow. Secondly, both types of modeling indicated the presence of buoyancy driven ventilation within the model. However, the air speed within the occupant's zone was too low to create physiological cooling. The term *Solar chimney* is used extensively in Barozzi's experiment as the *chimney* shape is quite obvious. In his study the term *Solar chimney* seems to be more suitable as the chimney takes the form of a roof (Barozzi, 1992).

#### **D. ISSUES OF RESEACH OBJECTIVES**

Air movement created by the stack effect is usually not adequate to achieve physiological cooling. It is less than the recommended air speed range for cooling of 0.15 to 1.5 m/s in tropical condition (Satwiko, 1994). It can be seen that two means are available for improving air movement: firstly, by increasing the air volume (stack height) and secondly, by increasing the air temperature difference. The indoor air temperature has to be kept low. All the above designs involve stack effect. However, in terms of construction (complexity, technology, etc.) and material (cost, durability, availability, etc.) these designs are not suitable for wide application in low cost housing in tropical countries.

Studies of solar-induced ventilation involve aerodynamic experiments on buoyancy problems which can be done using both physical modeling and computer modeling methods, while based on computational fluid dynamics (CFD). Both methods have advantages and disadvantages. Physical modeling is considered to give results that are easy to check. However, for an experiment which involves various model designs this method can become expensive and time consuming. The computer simulation method, on the other hand, allows easy modification of the design with more precise results in less time. Even though computer simulation has a high initial cost (for its hardware and software), the final cost might be lower than that of the physical experiment since changes in the model designs can be made easily.

The objective of this study is to :

- understand the possibility of using solar-induced ventilation in experimental room under Malaysian wind condition
- understand the performance of variety of solar-induced ventilation to increase stack induced ventilation

#### **E. METHODOLOGY**

##### **a. Model experiments**

A pilot testing using three models were simulated for solar induced ventilation study. To simplify the discussion, only the pilot testing and study simulation model are discussed. Figure 1. shows the pilot testing model and models simulation. The chimney pvc pipe in the pilot testing was 12 feet high and 0.5 feet diameter. The solar induced ventilation models are based from basic size experimental room (20 feet length x 12 feet width x 10 feet high) and uses metal partition.

### b. Tool

Several tools were used to obtain data on temperature, humidity, wind velocity, wind direction, and solar radiation in the area of the study. Air temperature and humidity data were measured using data logger. CFD Flo Vent were used to validate pilot testing model and simulation of the solar-induced ventilation model. Flovent is the most widely used software for modeling engineering fluid flows due to its robustness, accuracy, and user friendliness. Modeling was performed for three dimensional domain due to the large space involved. The computational grid is recommended to be set of maximum size. Therefore in following calculations the model, is basically divided into a grid of 0.5 m x 0.5 m x 0.5 m control volume. Additional grid points are embedded in the part of chimney, roof, walls, around the inlets and outlets.

### c. Procedure

In the pilot testing the data logger is set for every 5 minutes from 10.00 am to 18.00 pm. Data logger were positioned of three points on each pipe and one point outdoor (figure 1). In the CFD simulation, following boundary condition area used: the material and thickness are set as same as the base models; Inlets and outlets are set as the same as ambient temperature; climatic condition are set to the site climatic conditions.

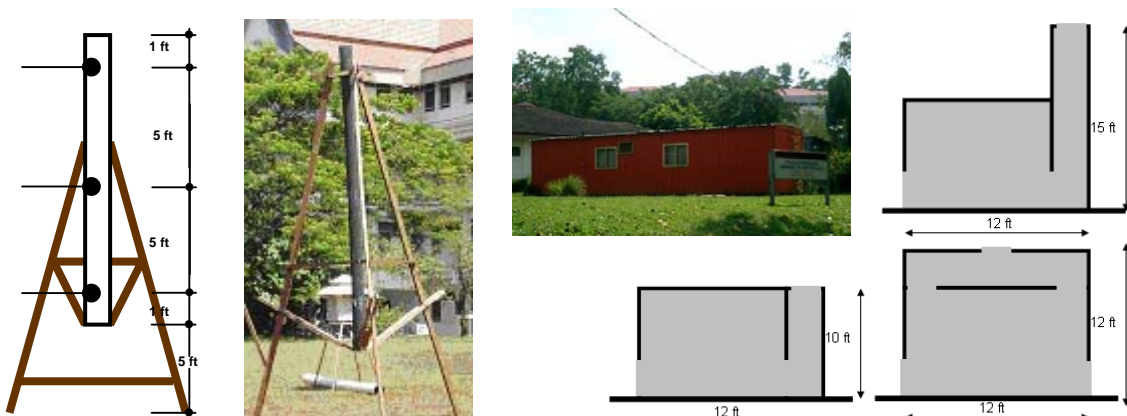


Figure 1. The models experiment (left) and pilot testing model for CFD model simulation (right)

## C. RESULT AND DISCUSSION

### a. Validation

Validation of the program was performed by comparing the measurement of pilot testing with the CFD simulation. Figure 2 shows the comparison of measurement and simulation result. It shows that the agreement between the measurement and simulation is generally good. The average difference between the measurement and simulation for ambient temperature was 0%; for black bottom was

about 3%; the maximum difference was 8% for the cavity 10 am of Black Top pipe. This gives confidence in using the computer code to study the air flow and temperature.

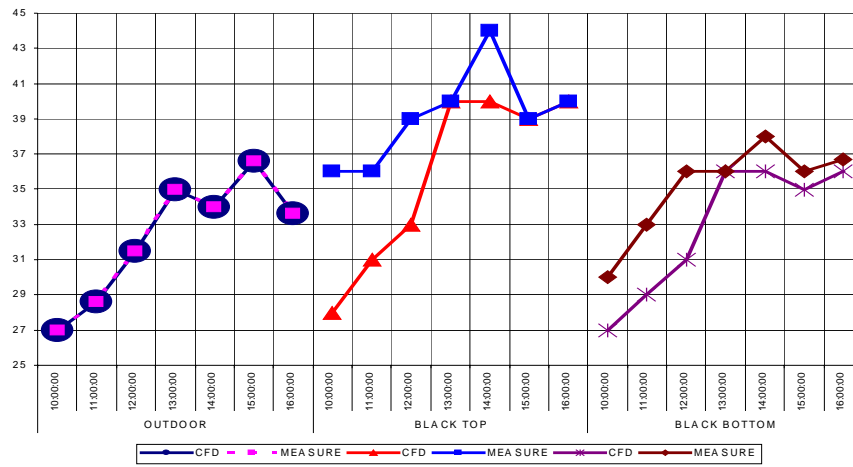


Figure 2. Comparing measurement and CFD simulation of pilot testing

b. Solar Induced Ventilation Simulation

Climatic data from weather station obtained from the pilot testing were used. The specific day chosen for the simulation and assumed as the hottest date of the year 21 march was. Times chosen 12.00 noon. The solar induced ventilation simulations were performed on selected model of trombe wall, solar chimney and solar roof. Figure 3 shows the simulation result for air velocity and temperature profile.

Model	Air velocity Profile	Temperature Profile
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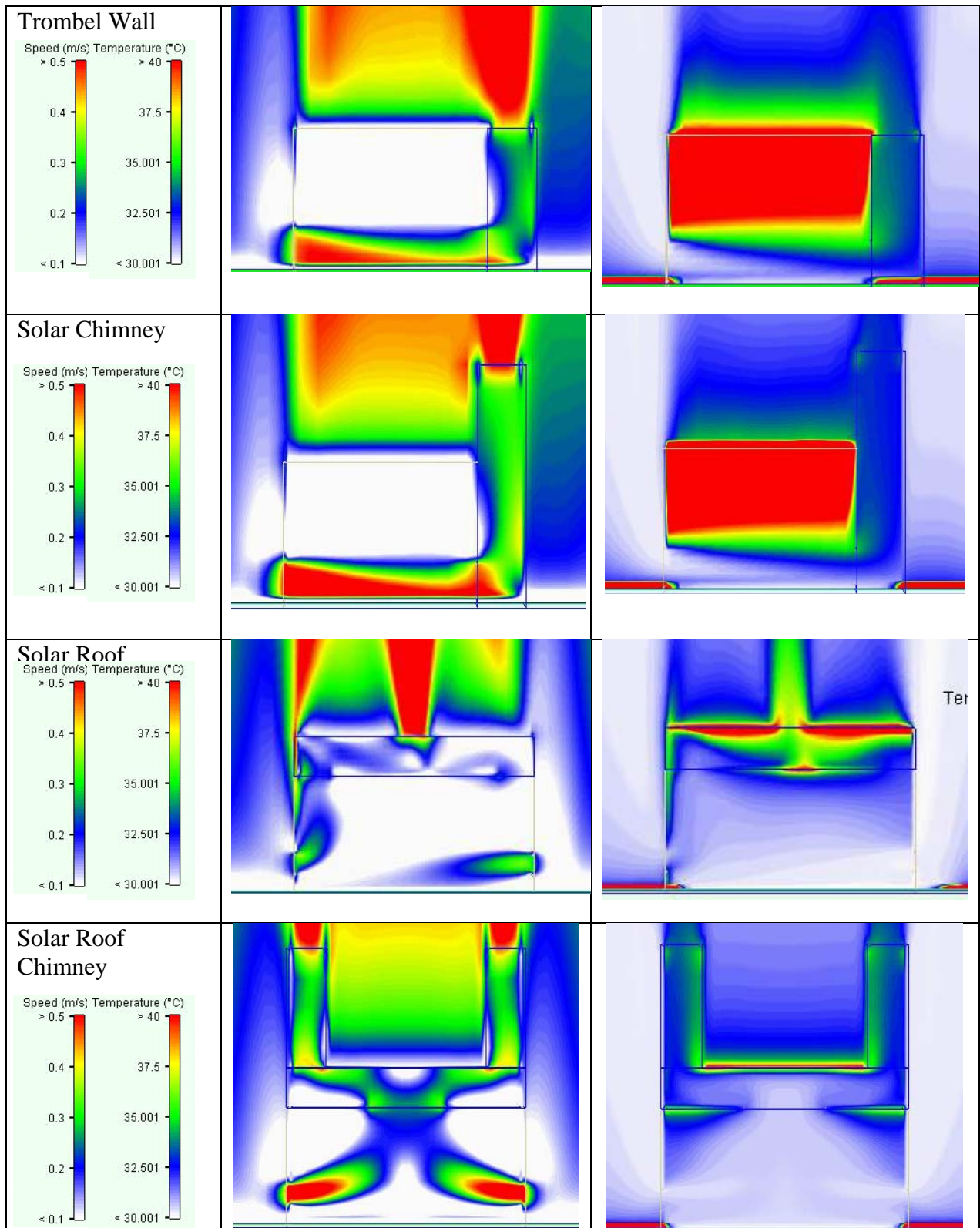


Figure 3. CFD simulation result of Solar Induced Ventilation

### c. Air Flow Profile

Air velocity on the tromble wall model and solar chimney model can increase air flow up to 0.5 m/s while air velocity in solar roof model until 0.3m/s. The position of 0.5 m/s air velocity in the tromble wall and solar chimney model depend

on the opening position. The position of 0.3m/s air velocity in the solar roof is only around the inlet of the room. The result indicated that stack induced performance of tromble wall and solar chimney were better than solar roof. Base of size air velocity zone, solar chimney model broader than tromble wall model.

#### d. Temperature Profile

Temperature profile on the tromble wall and solar chimney models can reach until 40°C (mostly in the room). These condition is uncomfortable temperature in the room. On the solar roof model, the double roof prevented the heat gain in the room.

#### e. Modification model

The above results showed that the use of solar chimney was able to increase air velocity while solar roof indicated less heat gains. By combining the solar chimney and solar roof the results indicated a better performance of air velocity and temperature reduction in the experimental room model

### D. CONCLUSION

The results showed that the solar chimney can increase air velocity in the room but also increase heat gain in the room. The results also indicated that solar roof reduced the heat gain but resulted in low air velocity. Use of solar wall can increase air velocity in the room depending on the orientation of the solar wall. Modification with combine solar chimney and solar roof will be use to improve the induced ventilation and further investigation will be done.

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