ภาคผนวก ข.
บทความในเอกสารประกอบการประชุมวิชาการที่พิมพ์เผยแพร่

Tienchutima, C., Chungloo, S., Tantasavasdi, C., Srisutapan, A. (2009). A Design Guideline for Highrise Condominium with Natural Ventilation. *The 4th International Symposium on Architecture and Culture in Suvarnabhumi: ISACS* (pp. 1-10). Chiang Mai: Faculty of Architecture, Chiang Mai University.

A Design Guideline for High-rise Condominium with Natural Ventilation

Chub Tienchutima, Sudaporn Chungloo, Chalermwat Tantasavasdi and Awiroot Srisutapan

Faculty of Architecture and Planning, Thammasat University

99 Moo 18, Klong 1, Klong Luang, Pathumthani 12121 email: acflute@hotmail.com

Abstract

Following the industrial and the commercial sectors, the residential sectors are the third most electric consumption with 70 percent of consumption goes to air-conditioning system. The energy consumption in the residential buildings increases due to the increase in city's condominium housing along the lines of Bangkok's skytrain system. This research is a design guideline of natural ventilation for 1 bedroom condominium with the size of 30-40 m^2, currently located near the skytrain system. The research simulates the condominium ventilation with Computation Fluid Dynamic (CFD) that was compared with the results from wind tunnel test. The evaluation of the thermal comfort of the occupants in condominium is based on temperature, air velocity and humidity obtained from the weather data of Thai Meteorological Department. The study includes the effect of condominium's opening area and position on the velocity and temperature in the room. With the comparison of thermal comfort hours and air-conditioning used hours between those typical condominium and condominium with efficient natural ventilation, the results demonstrate the high energy efficiency for the condominium with natural ventilation which provides useful information for constructor and consumer.

1. Introduction

Nowadays, energy consumption has become major factor in architecture design. Studies show that residential buildings are the 3rd most electric consuming sectors [1]. Around 40% of housing market is condominiums, consuming energy of more than 70 percent for cooling by air-conditioning system. The main idea of condominium is about room's size leading to congestion design and positioning of condominium, but preventing the use of natural ventilation. Considering Thailand a hot-humid country, the use of air-conditioning will consumes much more energy and the idea of creating energy efficiency by using natural ventilation design seems to be very interesting. [2-4]

To compare energy consumption between general condominium and that with natural ventilation, therefore this research composes the guideline for creating effective natural ventilation to provide information for both constructors and buyers. The objectives of this research are 1.) study the use of opening in residential building to provide good ventilating for the room considering general condominium's ratio of opening : room's size, opening position and building facade 2.) Study general condominium planning 3.) Design and develop the facade and opening for high efficiency ventilation considering room's air velocity 4.) Design and develop the planning with high efficiency ventilation considering room's air velocity, and 5.) Compare energy usage of air-conditioning system between general condominium and natural ventilating designed condominium. The research limits study to opening, facade and planning of 1 bedroom with 30-40 m^2 pricing 1-3 millions around Bangkok's skytrain's station. Simulation of the model room by Computation Fluid Dynamic (CFD) without taking into account of effects from rooms adjoined evaluates the thermal comfort in aspect of temperature, humidity and air velocity referred to information of Bangkok's weather in 10 years (1999-2009) provided by Thailand Meteorological Department. The research also compares electric consumption by air-conditioning system between general condominium and condominium with natural ventilating system.

This article includes the studies of thermal comfort of Thai people, the façade of existing condominium and the potential of using ambient air to produce thermal comfort and energy saving. The effective condominium façade for natural ventilation are suggested through the result of Computational Fluid Dynamic(CFD) program.

2. Initial Studies

2.1 Theories of Thermal Comfort

There are many studies concerning thermal comfort and results are different even it was done in the same area. One of the reasons are the concerns of personal feeling. ASHRAE [5] has decided it to be 26°C, relative humidity at 60-90% and air velocity between 0.1-1.68 m/s. Thermal comfort for hot and humid area by Lechner [6] is 28-31°C, 25-30% and the increase of air velocity by 1 m/s one will feel like temperature drops by 3°C. Jitkhajornwanich [7] have done a research in Thailand and his thermal comfort is 25-31°C, 62.5-90% and air velocity at 0.8 m/s. Khedari [8] and his team derived the comfort zone of 27-36.3°C and 50-80% when air velocity increased by 0.2-3 m/s (table 1) which agreed with Lechner's but also stated that air velocity at 0.25-1.5 m/s is more suitable to work (table 2).

This research chose Khedari's thermal comfort tables as his research was done in Thailand and the result was agreed by others' results.

Air Velocity (m/s)	Acceptable Temperature Range (°C)
0.2	27.0 – 29.5
0.5	28.5 – 30.8
1.0	29.5 – 32.5
1.5	31.0 – 33.8
2.0	31.2 – 26.0
3.0	31.6 – 36.3

Table 1. Cooling effect of air movement [8].

Air Velocity (m/s)	Thermal Comfort
0.00-0.25	Being ignorant of wind
0.25-0.50	Feeling Pleasantness
0.50-1.00	Becoming aware of wind
1.00-1.50	Cooling effect by wind
> 1.50	Feeling unpleasantness

Table 2. Feeling of comfort according to air velocity [9].

2.2 Theories of Natural Ventilation

There is relation between air flow, air temperature and air pressure. Air flows from high pressure area to low pressure area and if the different is higher then air will flow faster. Temperature different also have an effect as hot air floats up and colder air flows in place [10]. ASHRAE [11] stated air stream colliding with the building of 2/3 goes down and the 1/3 goes up. When building's height is 3 times or more compare to width, there is space where air neither go up or down, calling the air splitted point. (Fig.1)

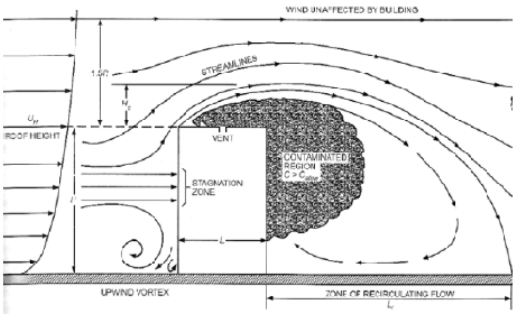


Fig. 1. Flow patterns around rectangular building [10].

Further more, Evola and Popov [12] has studied air flow where there is only one building's opening, i.e. single-sided ventilation, there is almost no horizontal flow. Gan [13] stated that in the room with one opening, air speed is faster near the opening and it is getting slower further away. Chen [14] has done the experiment about single-side ventilation in suite room of 62 m^2 with 2 openings, one at upper part and another at lower part me the wall. There are computer, TV and human acted as the heat sources in the room. He found that outside air velocity of lower than 3 m/sec, hot air buoyancy force is stronger than the pressure force at opening. This causes air flows into the room through lower opening and flows out through the upper one. As air is faster than 3 m/sec, it happened in vice versa. Munir [15] has studied about cross ventilation where there are two opening, one on the right side and another on the left side of the building. He found that air flow of 45° against building and there is a wing-wall at the window, it will help keeping air inside and increase air speed in the room. Givoni [16, 17] conducted experiment about placing wing walls between two openings. He found that the wall causes different in pressure between the two openings as air flowing does not go perpendicular against the building. He also stated the length between two wing-wall and the opening area shows insignificant effect on air speed. He added that Chandra's research showed the same result. Also, Mak [18] has done the research in similar way of Givoni and found that air turbulence intensity doesn't have effect on in-room air speed.

For another Architectural factor, Chand and his group [19] found that a balcony in front of opening in one side-opening room showed effect of air pressure.

In conclusion, ventilation through single-side opening of the room, can be increased by application of wing wall and the balcony is the important architectural object to alter air pressure and then make natural ventilation possible.

3. Analysis of Initial Study

3.1 Thailand Climate Analysis

Thailand is a country in tropical climate which means temperature and humidity are always high and small difference in air temperature. Northeastern monsoon and Southwestern monsoon are two main monsoons effecting Thailand. Study of hourly temperature collected by Thailand Meteorological Department during 1999-2008 stated that average monthly temperature is between 24.44-31.89°C, highest in April of 31.89°C and lowest in December of 24.44°C. Average monthly humidity is between 55.52-82.58%, which is highest in October with 82.58% and lowest in December with 61.84% (Fig 2.)

Beside, average air velocity in 10 m-height area around city's center is between 0.8-1.48 m/sec, the largest and lowest values occur in March and in December, respectively (Fig. 3). In this study, we assume that the outdoor temperature within the range of thermal comfort of 28.5-33.8^{O}C is flowing into the room. With the appropriate design of the building façade and the wing wall, the air velocity inside the room is expected to remain in the range of thermal comfort of 0.5-1.5 m/s. Taking into account the weather data of 8,760 hours per year, Table 1 shows that temperature and velocity in the comfort zone is 3,710 hours or 43.4%. This means the total hours of shutting down the air conditioner. Energy savings per one room (6 x 6 m^2) of the condominium can be primarily computed as shutting down 1.1 kW/ton refrigeration for 3,710 hours or 1.1 kW x 3710 hours = 4,081 kWh per year.

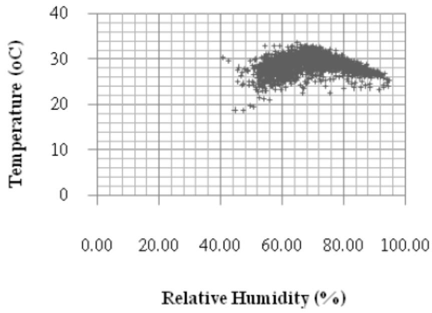


Fig. 2. ploting of temperature and humidity of weather data of Thailand.

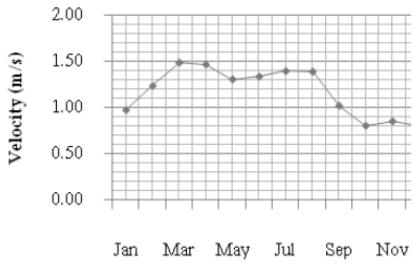


Fig. 3. Average air velocity from the weather data of Thailand.

3.2 High-rise Condominium Physical Analysis

Physical exploration of the existing condominiums shows that 1.) The rooms' size are around 30-40 m^2 and the price range is around 1-3 million baht. Rooms situate around Bangkok Skytrain's stations which belong to the sample population found most. 2.) Rooms' figure is both square and rectangle. There is no exact ratio of proportion because of the building's size, common corridor and other factors. 3.) There are six types of facade 4.) Room's space divides into 4 parts as bedroom, living, kitchen and bathroom. There are two types of zoning. Positions of the living area are that next to the opening or that on the right or left side of the room (Fig. 4).

Opening of high-rise condominiums has showed that 1.) Openings with balcony in front of it are 2 m. height or 2.05 m. include the stiles. There is no exact ratio of opening's width and it can be divided into 2 types: the single sash opening and the double sash opening (Fig. 5). 2.) Openings without balcony in front of it are 1.1 m. height and 0.85 m. from the floor. Stiles' height is 2.05 m. There is no exact ratio of opening's width and it can be divided into 3 types: the single, the double sliding window and the pivot window (Fig. 5).

The survey and exploration show that, currently, there are many uses of facade and openings with different width. So this research will comply to ministerial regulation with 6x6 m^2. square room which is the mean width so the effected of room's depth is negligible.

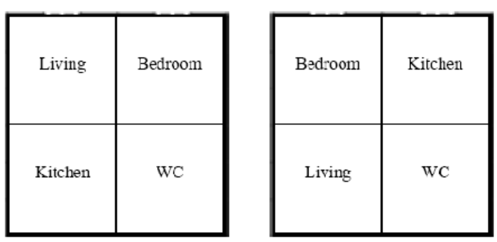


Fig. 4. Type of zoning in the current condominium.

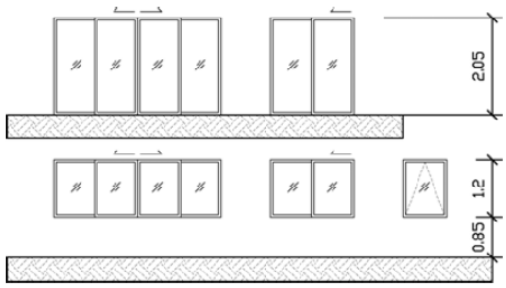


Fig. 5. Type of Opening

4. Simulation results and Discussions

4.1 CFD Model Setup

Based on the CFD Program [20], the domain (X,Y,Z) are 1,482, 1,926 and 840 respectively. The mean wind speed is obtained from Bangkok's average air velocity at 10 m height (H_{met}), which is 1.17 m/s (U_{met}). Air velocity (U_H) of different height level (H) can be calculated by using the following formula.

$$U_H = U_{met}(\delta_{met} / H_{met})^{a_{met}}(H/\delta)^a$$

U_H : mean wind speed at height H

U_{met}: meteorological station hourly wind speed, measured at height H_{met}

H : wall height above ground on upwind building face

H_{met}: height of anemometer at meteorological station

δ : wind boundary layer thickness at local building terrain, 460 m for large city center

δ_{met}: wind boundary layer thickness at meteorological station, 370 m for suburban

a : exponent for local building terrain, 0.33 for large city center

a_{met} : exponent for the meteorological station, 0.22 for suburban

4.2 Simulation Result and Analysis

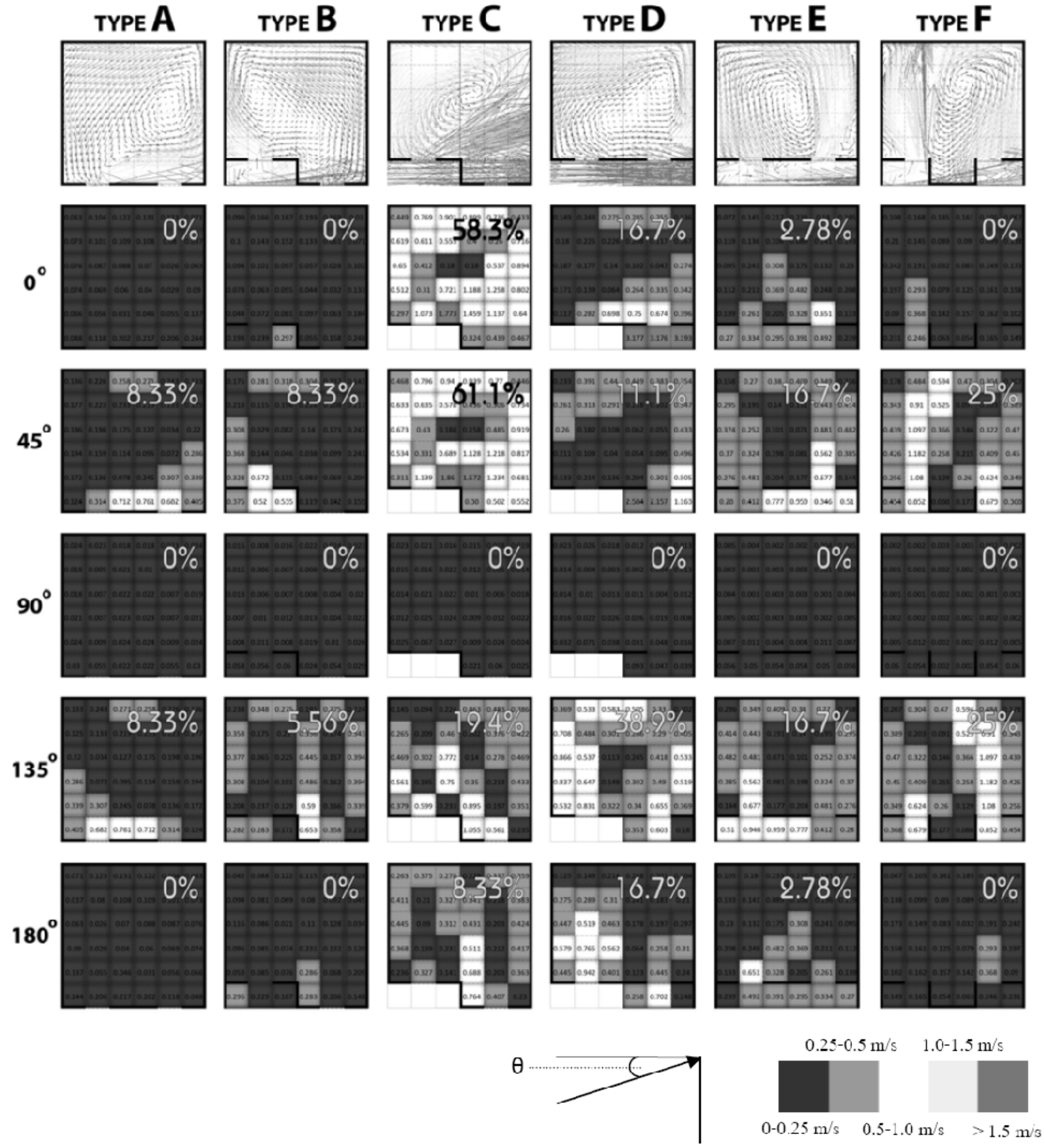


Fig. 6. Ventilation rate in room's area

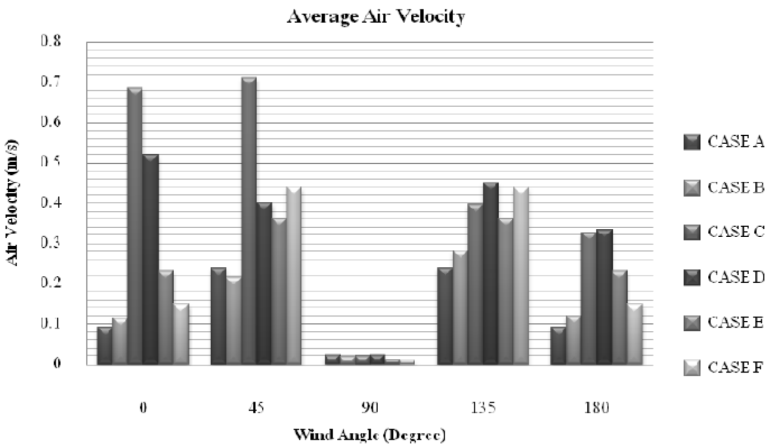
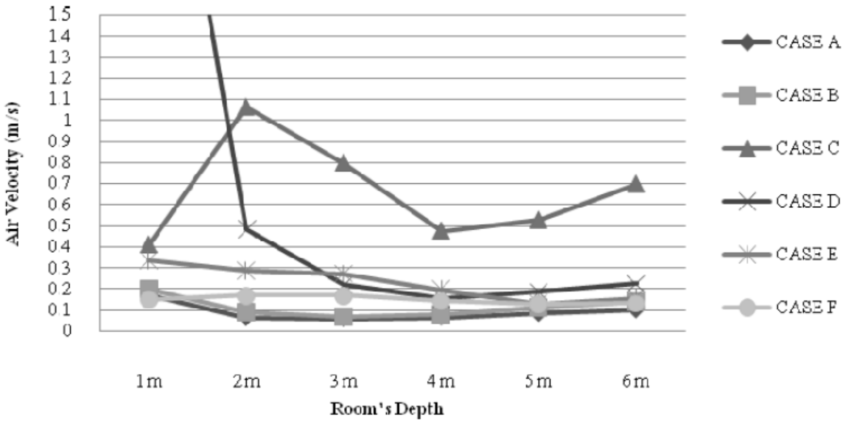
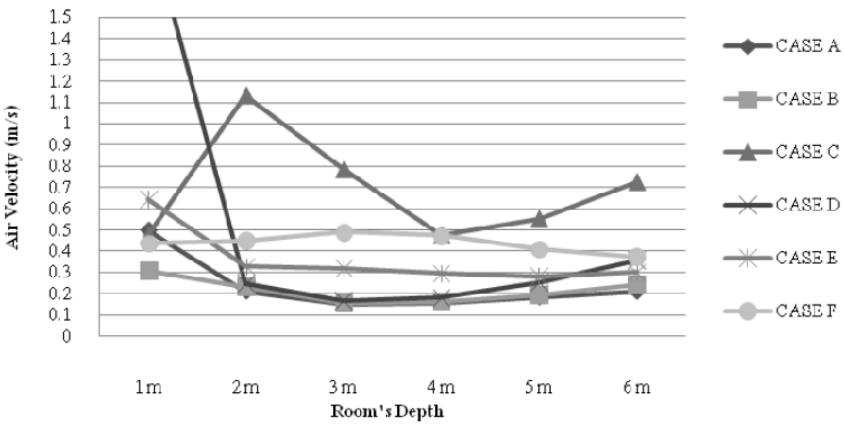


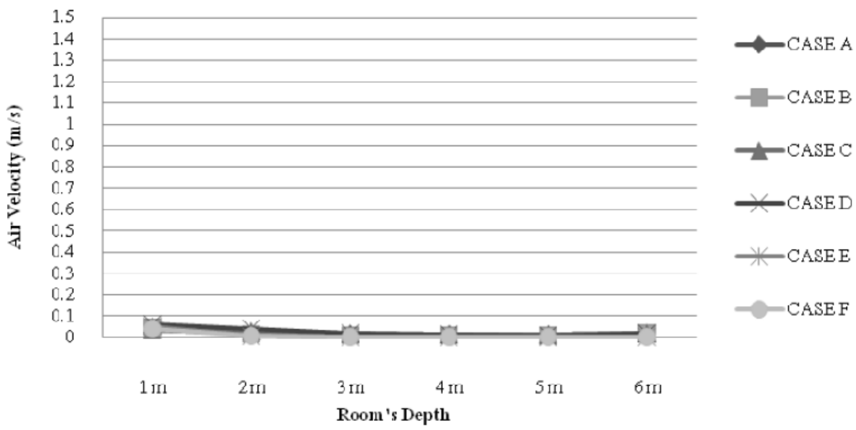
Fig 7. Average air velocity



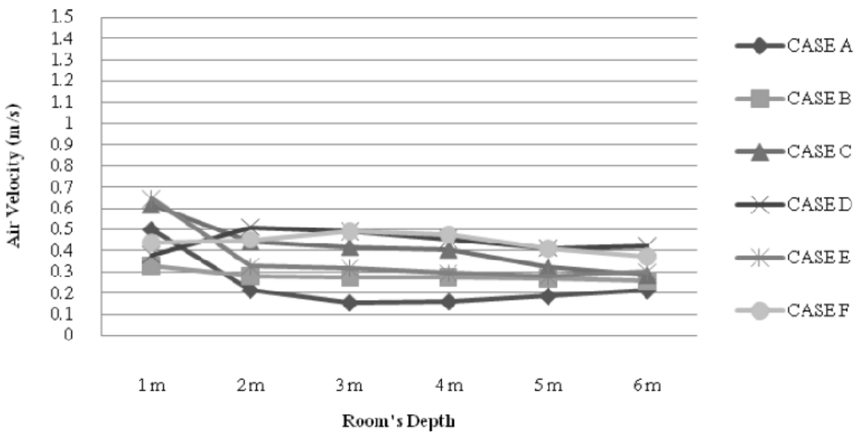
(a) Wind angle 0°



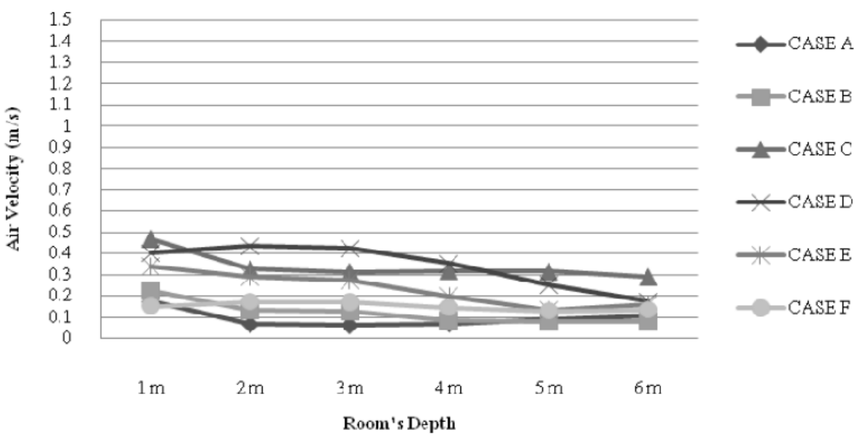
(b) Wind angle 45°



(c) Wind angle 90°



(d) Wind angle 135°



(e) Wind angle 180°

Fig. 8. Average air velocity of room's depth in wind angle 0°-180°

Room with wall extended from the building will get faster air velocity than flatted wall room because of the different in air pressure between the two openings. Type C room is the most efficient in using natural wind if air flow from 0° and 45° direction with 58.3-61.1% of the room can be able to feel the airflow and air velocity is 0.685-0.712 m/s which are very high numbers. Type D room is the most efficient in using natural wind if air flow from 135° and 180° direction with 16.7-38.9% of the room be able to feel the airflow and air velocity is 0.33-0.45 m/s. For 90° direction, every room type got bad result with velocity slower than 0.25 m/s. (Fig. 6-7)

Considering the average air velocity of each depth level inside the room, air flow from 0° and 45° direction has the highest speed around the area close to the opening. The further the depth from the opening, the slower the air speed is. The air flow gets stronger again at the back of the room except in room type E and F. However, considering air flow from other directions, the air velocities of any depth are quite similar. (Fig. 8)

5. Conclusions and Further Study

The pilots test shows that wing walls of buildings can help increasing single-sided ventilation except for air flow from 90° direction. The wing walls can create the most effective when it is located on the windward side. The velocity of greater than 0.5 m/s, obtained from the facade and wing walls design, can be used as natural ventilation that results in 43.4% of energy savings from air conditioner.

The further study includes simulations of the width of the wing walls, distance between openings, internal partition and having balcony at the opening. The result of the experiment will used for assessing the comfort zone and calculating the extent of energy saving from air conditioning.

Acknowledgement

The author would like to thank the National Metal and Materials Technology Center (MTEC) and the eXcellent Center for Eco-Product Development (XCEP) for partially supporting the scholarship (TGIST plus XCEP) for this research.

Reference

[1] Ministry of Energy. (2008, 6 August). *Annual report 2008 ministry of Energy*. From http://www.energy.go.th/moen/upload/File/Annual%20report%202008/06_situation.pdf

[2] The Department of Alternative Energy Development and Efficiency (DEDE). (2008, 20 August). *A Study on the Conditions of Energy Consumption and Guildlines to Promote Energy Conservation in the Residential Sector*. From http://www2.dede.go.th/new - homesafe/webban/actionplan.htm

[3] Khongchantr, W. (2009, 14 February). *สถานการณ์ล่าสุด ซิตี้คอนโดฯ ณ มกราคม 2550 สิ้นตลาดหรือไม่สิ้น ???*. From http://www.area.co.th/English/ws_article/default_previews.php?strquey=article9.php&year=2550&no=6

[4] Khongchantr, W. (2009, 29 June). *ทิศทางตลาดที่อยู่อาศัย ปี 2552*. From http://www.area.co.th/English/ws_article/default_previews.php?strquey=article17.php&year=2552-02-02&no=2

[5] American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). (2004). ANSI/

ASHRAE standard 55-2004: *Thermal environment conditions for human occupancy*. Atlanta: GA, ASHRAE.

[6] Lechner, N. (2001). *Heating, cooling, lighting: Design methods for architects (2nd ed.)*. New York: John Wiley & Sons.

[7] Jitkhajornwanich, K. (2007). *Thermal Comfort and Adaptability to Living for Local People.* Nakorn Pathom: Research & Development Institute, Silpakorn University.

[8] Khedari, J., Yamtraipat, N., Pratintong, N., & Hirunlabh, J. (2000). *Thailand ventilation comfort chart*, Energy and Buildings, 32, 245-249.

[9] Olgyay, V. (1963). *Design with climate: A bioclimatic approach to architectural regionalism*. Princeton, Princeton University Press.

[10] Moore, F. (1993). *Environmental Control System: Heating Cooling Light.* Singapore, McGraw-Hill

[11] American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE). (2005). *ASHRAE Fundamental 2005*. Atlanta: GA, ASHRAE.

[12] Evola, G. and Popov, V. (2006). *Computational analysis of wind driven natural ventilation in buildings,* Energy and Buildings, 38, 491-501.

[13] Gan, G. (2000). *Effective depth of fresh air distribution in rooms with single-sided natural ventilation*, Energy and Buildings, 31, 65-73.

[14] Chen, Q., Allocca, C., Glicksman, L.R. (2003). *Design analysis of single-sided natural ventilation,* Energy and Buildings, 35, 785-795.

[15] Munir, A. and Wonorahardjo, S. (2004). *The Performance of Single-sided Natural Ventilation Induced by Wind-driven Flow,* Banda Aceh, Laboratory of Building Science.

[16] Givoni, B. (1976). *Man, Climate and Architecture.* London: Applied Science Publishers.

[17] Givoni, B. (1994). *Passive and low energy cooling of buildings*. New York: John Wiley & Sons.

[18] Mak, C.M. (2007). *A numerical simulation of wing walls using computational fluid dynamics,* Energy and Buildings, 39, 995-1002.

[19] Chand, I., Bhargava, P.K., Krishak, N.L.V. (1998). *Effect of Balconies on Ventilation Inducing Aeromotive Force on Low-rise Buildings,* Building and Environment, 33, 385-396.

[20] CHAM. (2002). *PHOENICS version 3.5*. London: CHAM