Optimize the Percentage of Opening Area due to Thermal Comfort in Hot Humid Residential

(Using Eco House as Model Simulation)

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ABSTRACT

Overheating is a specific problem in hot humid climate, especially when the outdoor temperature is over the standard temperature of human thermal comfort. One of several efforts to achieve indoor thermal comfort is by passive cooling systems. The most effective passive cooling system for the hot humid climate is by using natural ventilation system.

Opening in the building is one of component of natural ventilation system. This paper work explains effects of different opening area percentage (35%, 43% and 67%) toward air circulation each hour required and thermal comfort. The observation object is Eco-house model that simulated by ARCHIPAK and AIOLOS programs.

The simulation shows opening area percentage that provides optimally air change per hour required and thermal comfort is 43 % opening area.

Key Word : ***opening area percentage, thermal comfort, hot humid climate***

1. INTRODUCTION

Indonesia is a hot humid climate country, which is identified by having high temperature, humidity, and heavy rain. The wind speed is approximately 1 m / sec in raining season and about 2 m/sec in summer (Santosa, 1997). High temperature and humidity give great effect to the thermal comfort of building's occupants, which is over heat. The optimum passive cooling strategy for physical condition in hot humid climate is by breaking rate of heat and maximizing wind flow to eliminate heat accumulation to the building (Santosa, 2000 ; Szokolay, 1987). Maximizing wind flow is a passive cooling method that is used to spread human comfort zone (Szokolay, 1987).

Opening design which is including orientation, width, and type of opening are the variables of successful ventilation system. This paper will observes opening area percentage which is fulfilling the optimum thermal comfort and air change.

The method used on this paper work is model simulation by changing the variable of width opening percentage. The simulation used is thermal activity simulation : ARCHIPAK and ventilation system simulation: AIOLOS. Simulation program ARCHIPAK is used to predict indoor thermal condition and program AIOLOS is used to focus indoor wind flow rate. Cross value of these simulation programs into field condition are for ARCHIPAK : +/- 0.56 and AIOLOS : +/- 0.23.

From the result of this simulation, optimum opening area which is able to achieve thermal comfort and indoor air change will be observed.

2. HOT HUMID CLIMATE

Climate is one of many aspects that determine architectural forms. So the solution of architectural forms should maximize beneficial climate potential and minimize unbeneficial ones. In broad outline data of hot humid climate (Surabaya city) can be seen in Table 2.1.

Table 2.1.Data of Hot Humid Climate

Climate Data	Rainy Season (Des-Mar)	Summer Season (Sep-Nop)
- Average Maximum Temperature	31°C	33.2°C
- Average Maximum Temperature	25°C	25.6°C
-Average Temperature in one year	4.5°K	
-Average Relative Humidity	88%	70%
-Average Sun Rays Time	7.8 hour	11.4 hour
-Rainfall	14202 mm	280.6 mm
-Average Wind Speed	1.0-2.5 m/det	1.0-4.3 m/det
-Wind Direction	West	East
-Global irradiance (max)	780 Wh/m^2	1300 Wh/m^2

Source: Santosa, 2000 updated

Early analysis of thermal condition in hot humid climate (Surabaya) shows about 68% thermal load is above comfort limit of building occupant, also only 32% thermal condition is at or below comfort limit (Santosa, 2000). Overheated period is in high noon, after 09.00 am. During that time, global irradiance is already reaching 800 Wh/m^2, until 15.00 pm. While under heated period is after sunset until sunrise the day after. Other climate aspect shows high wind speed is having potential to eliminate heat over buildings and able to achieve physical comfort of building occupant.

3. THERMAL COMFORT AND NATURAL VENTILATION SYSTEM

Thermal comfort is a condition when people is in a condition that is not too hot or too cold, and also not causing uncomfortable feelings (Markus & Morris, 1980). That condition is related to climate condition (location), building condition and building occupants (Santamouris, 1996)

Two parameter of comfort thermal measurement are :

1. Physical parameter; which is thermal condition of the environment : temperature, humidity and wind flow.
2. Physiology parameter; which is human as measuring device, it is related to the building occupants' characteristics, age and gender (Allard, 1998)

From result of experiments been done, shows that in hot humid climate, temperature that is fulfill human thermal comfort is 26°C- 28.9°C (Santosa, 1997).

One of thermal comfort achievement strategy is by passive cooling natural ventilation system. It is not only eliminate heat accumulation, but also maintaining air quality to supply fresh air and change dirty one. Indoor air supply need is related to air change gained in each hour. Aynsley (1977) explained air change need in ventilation rate which fulfills qualification in Table 3.1.

Table 3.1. Qualification air change need in m3/hour for each room .

Function of room	***Ventilation rate m^3/h fresh air***
- Living room	45
- Bed room	25
- Kitchen	60-90
- Bath room	25

Source: Aynsley, 1977

Natural air is influenced by outdoor condition and also by building design and opening design, which are : building type, opening location at building coverage, number of opening at the same side, width opening, opening orientation and type (Givoni, 1979).

From experiment's result done by Evans (1980) shows that in specific width opening percentage, increase of wind speed is no longer effective. This paper work will change the variable of opening area percentage based on the phenomena of the residential natural ventilation system at hot humid climate.

4. ANALYSIS OF OPENING AREA PERCENTAGE

The object observed is Eco-House residential model. This building is a 3-level raised building. Variable object will be simulated in the hottest month (October) and the coolest (January). Opening area percentages are 35%, 43% and 67%. There are from the previous experiment of observation at phenomenal width opening at traditional house (Apritasari, 2003). Building description at fig. 4.1, 4.2. and 4.3.

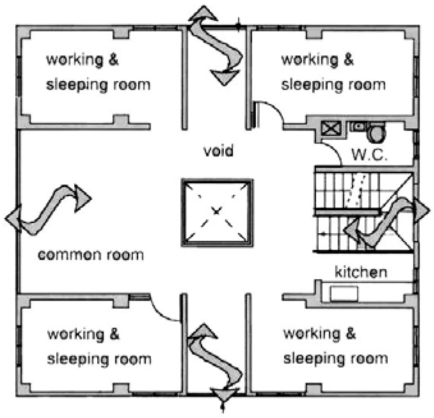

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fig. 4.1.Plan of Eco-House
Source: Nastiti, 1999

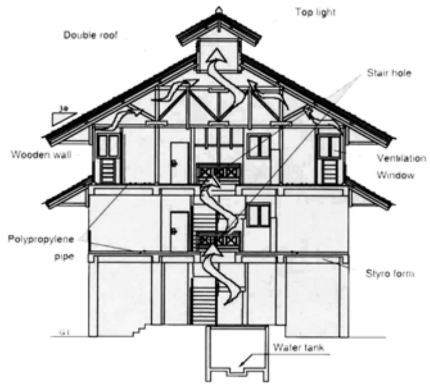
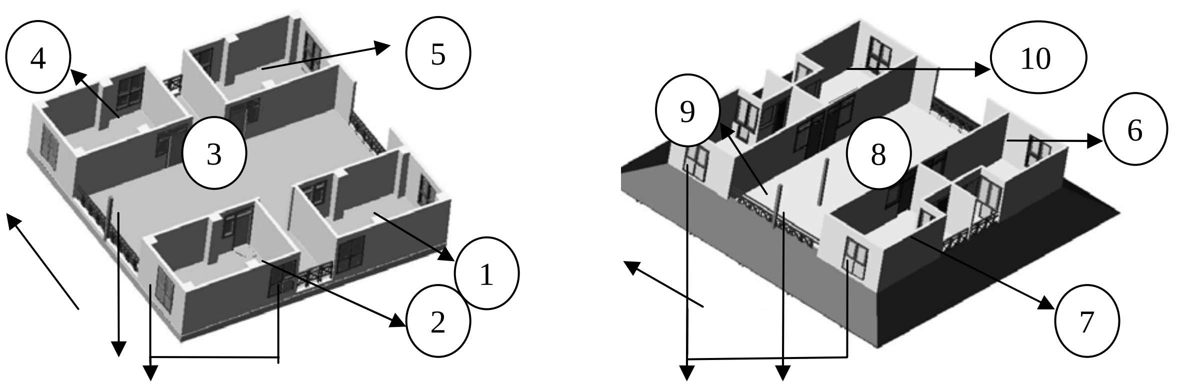


fig. 4.2. Section of Eco-House
Source: Nastiti, 1999

fig. 4.3. Elevation of Eco-House
Source: Nastiti, 1999

Opening position which opening area percentage is changed can be seen at fig. 4.4.



Opening position which opening area percentage is changed
2nd Floor

Opening position which opening area percentage is changed
3rd Floor

fig. 4.4. Axonometric of changed opening area percentage

Not all opening is opening area percentage changed. At zone 1, 2, 4 and 5 external opening area is changed. At zone 3, opening area changed is only at East and West side, while at South and North side opening area is not changed. At zone 6 and 10, changed opening is at East side. While at zone 7 and 9, changed opening is at West side . And at zone 8, changed opening is at East and West side. More details can be seen at Table 4.1.

Observation is taken only at zone 1, 3 and 4 in 2nd floor, and zone 6, 8 and 9 in 3rd floor. Not all zones are evaluated because some rooms have the same opening characteristic.

Table. 4.1. Data of Opening Area Percentage *Eco-house* models

		35 % wall area		**43% wall area**		**67% wall area**	
	Position	**Width (m^2)**	**Type**	**Width (m^2)**	**Type**	**Width (m^2)**	**Type**
Zone 1	South	4.05	Casement	5.4	Casement	6.75	Casement
	East	2.43		3.24		4.05	
Zone 2	South	4.05	Casement	5.4	Casement	6.75	Casement
	West	2.43		3.24		4.05	
Zone 3	East	4.86	Casement	6.48	open	8.1	open
	South	3.6	open	3.6	open	3.6	open
	West	4.86	Casement	6.48	open	8.1	open
	North	3.6	open	3.6	open	3.6	open
Zone 4	North	4.05	Casement	5.4	Casement	6.75	Casement
	West	2.43		3.24		4.05	
Zone 5	North	4.05	Casement	5.4	Casement	6.75	Casement
	East	2.43		3.24		4.05	
Zone 6	East	2.43	Casement	3.24	Casement	4.05	Casement
	West	1.78		1.78		1.78	
	South	2.7		2.7		2.7	
Zone 7	West	2.43	Casement	3.24	Casement	4.05	Casement
	East	1.78		1.78		1.78	
	South	2.7		2.7		2.7	
Zone 8	East	4.86	open	6.48	open	8.1	open
	West	4.86		6.48		8.1	
Zone 9	West	2.43	Casement	3.24	Casement	4.05	Casement
	East	1.78		1.78		1.78	
	North	2.7		2.7		2.7	
Zone 10	East	2.43	Casement	3.24	Casement	4.05	Casement
	West	1.78		1.78		1.78	
	North	2.7		2.7		2.7	

- **Natural Ventilation System**

Simulation result shows average of air change per hour at the hottest and coolest month. It shows that the bigger opening area percentage make the larger average of air change per hour gained. Air change per hour gained at the hottest month is bigger than at the coolest one. This is caused by temperature difference at the hottest month is larger than the coolest one, and the wind speed at the hottest month is higher than the coolest one (fig.4.5 and fig.4.6).

Opening area and orientation influence the position of inlet and outlet. Zone 1, 4 and 8 have openings that is oriented at dominant wind direction, with the same width inlet and outlet percentage, so the indoor wind speed is stabilized. At zone 3, inlet is smaller than outlet, so indoor wind speed is increasing. At zone 6 and 9, inlet opening area percentage is bigger than outlet, so wind speed is decreasing.

Openings at this model house are facing dominant wind direction, so volume of air change gained is large. Zones with openings at East side, at the hottest month will get upright wind flow from East. So do zones with openings at West side, at the coolest month will get upright wind flow from West side. At zone with openings at East and west side, at the hottest and coolest month will get dominant upright wind flow.

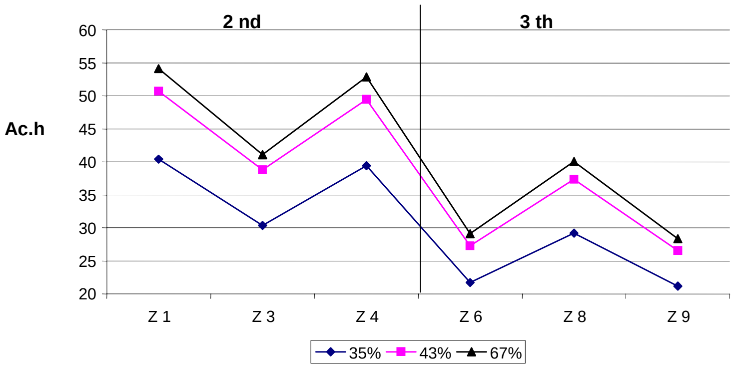


Fig .4.5. Average air change per hour gained, opening area percentage 35%, 43% and 67% at the hottest month

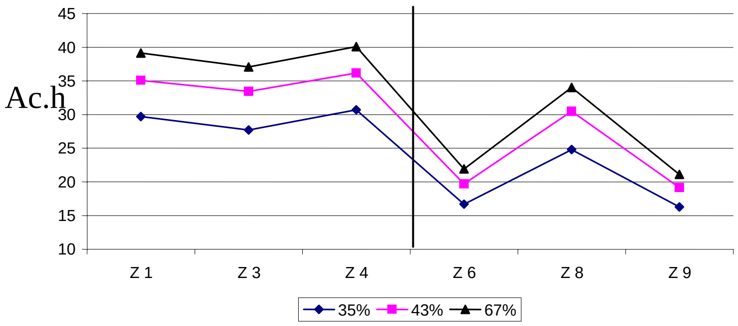


Fig. 4.6. Average air change per hour gained, width opening area percentage 35%, 43% and 67% at the coolest month

Result of the simulation also shows that face to face cross ventilation system gain less volume air change than side by side one. This is because, for upright orientation wind course, side by side cross ventilation system will give faster wind speed then the face to face one.

Air change gain is also influenced by room volume. Zones at 2nd floor have smaller volume than the ones at 3rd floor. While width opening of 2nd and 3rd floor are equal, so there is different volume of gained air change. Air change at 2nd floor is bigger than at 3rd floor.

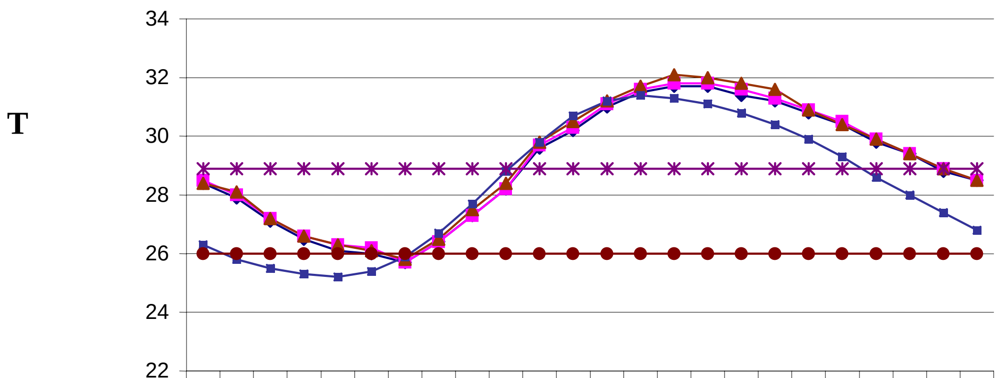
Figure 4.5 and 4.6 shows the bigger width opening percentage the larger volume of air change. Increasing volume of air change from 35% to 43% shows quite much air change volume, while increasing air change volume from width opening percentage 43% to 67% does not show significant air change gained. This is also happening during increasing period of air change volume which fulfill qualification (Table 4.2.)

Table 4.2. Increasing opening area percentage toward average increasing percentage ac.h and period ac.h fit to qualification

Increasing % Width Opening	**% increasing *ac.h***		**Increasing period *ac.h* fit the qualification**	
	Hottest Month	**Coolest Month**	**Hottest Month**	**Coolest Month**
35% to 43%	25%	18%	1.3 jam	1.3 jam
43% to 67%	8%	12%	0.25 jam	0.25 jam

- **Thermal Comfort**

Next observation is observation of thermal condition of these three models. Shape of geometric forms are equal, the differences of heat gaining is at transparent materials which is receiving heat. The larger transparent wall the bigger heat solar radiance received.



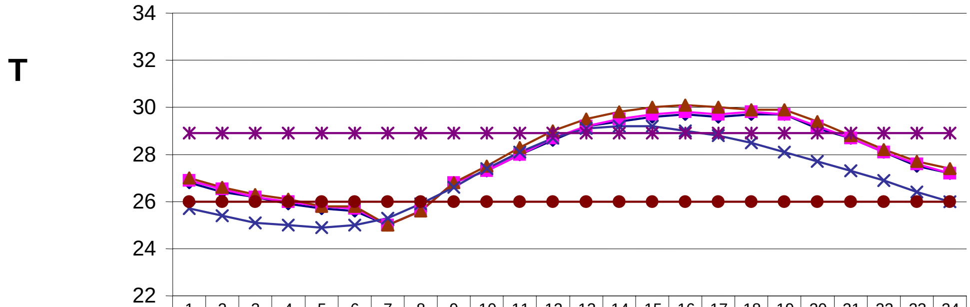
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
35%	28.4	27.9	27.1	26.5	26.1	26	25.7	26.4	27.3	28.2	29.6	30.2	31	31.5	31.7	31.7	31.4	31.2	30.8	30.4	29.8	29.4	28.8	28.5
43%	28.5	28	27.2	26.6	26.3	26.2	25.7	26.4	27.3	28.2	29.7	30.3	31.1	31.6	31.8	31.8	31.6	31.3	30.9	30.5	29.9	29.4	28.9	28.5
67%	28.4	28.1	27.2	26.6	26.3	26.1	25.8	26.5	27.5	28.4	29.8	30.5	31.2	31.7	32.1	32	31.8	31.6	30.9	30.4	29.9	29.4	28.9	28.5
To	26.3	25.8	25.5	25.3	25.2	25.4	25.9	26.7	27.7	28.8	29.8	30.7	31.2	31.4	31.3	31.1	30.8	30.4	29.9	29.3	28.6	28	27.4	26.8
Ta	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9
Tb	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26

Hour

Fig. 4.7. Temperature profile different opening area percentage at 35%, 43%, and 67% on the hottest month

Note to :outdoor temperature, ti : indoor temperature, tb : the lowest temperature of thermal comfort, ta : the highest temperature of thermal comfort

Source : simulation of thermal behavior ARCHIPAK



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
35%	26.8	26.4	26.2	25.9	25.7	25.6	25	25.6	26.8	27.3	28	28.6	29.2	29.4	29.6	29.7	29.6	29.7	29.7	29.1	28.7	28.1	27.5	27.2
43%	26.9	26.5	26.2	26	25.8	25.7	25	25.6	26.8	27.3	28	28.7	29.2	29.5	29.7	29.8	29.7	29.8	29.7	29.2	28.7	28.1	27.6	27.2
67%	27	26.6	26.3	26.1	25.8	25.8	25	25.6	26.8	27.5	28.3	29	29.5	29.8	30	30.1	30	29.9	29.9	29.4	28.8	28.2	27.7	27.4
To	25.7	25.4	25.1	25	24.9	25	25.3	25.9	26.6	27.4	28.1	28.7	29.1	29.2	29.2	29	28.8	28.5	28.1	27.7	27.3	26.9	26.4	26
Ta	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9
Tb	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26

Hour

Fig. 4.8. Temperature profile different opening area percentage at 35%, 43%, and 67% on the coolest month

Note to :outdoor temperature, ti : indoor temperature, , tb : the lowest temperature of thermal comfort, ta : the highest temperature of thermal comfort

Source : simulation of thermal behavior ARCHIPAK

This can be observed from room temperature of the three models. At the hottest month, average indoor temperature is 29°C (35%), 29.1°C (43%) and 29.2°C (67%). At the coolest month average indoor is 27.7°C (35%), 27.8°C(43%), and 27.9°C (67%). From three different opening area percentage, 67% width opening have the highest average temperature. But 0.1°K temperature difference does not influence the sensation of building occupants.

Thermal comfort period of three model at the hottest month have the same period : 12 hours (50%, 23.00-10.00 period), as overheating period : 12 hours (50%, 11.00-22.00). At the coolest month thermal comfort period width opening 35% and 43% is increasing 66.7% (16 hours, 21.00-12.00), and overheating condition is 33.3% (8 hours). At width opening 67% thermal comfort period is 54.23% (13 hours, 21.00-11.00) and overheating condition 45.8% value (11 hours, 12.00-20.00). More details can be seen at Fig. 4.7 and 4.8.

Different width of transparent and massive walls will give different heat load. Heat load achieved from sunrays radiance and ventilation heat. Different width opening percentage will give different cooling degree hour. Histogram 4.9. shows cooling degree hour in one day of the hottest and coolest month. Maximum cooling degree hour occurred at width opening percentage 67%, which is 24.3 K.h (October) and 6.1 K.h (January).

From the analysis above, optimum opening area percentage chosen is 43% width wall. At this percentage air change volume gained relatively big and cooling degree hour is not too big than opening area 67%. While opening area 67% air change volume gained is not far to different than 43%, but have high cooling degree hour.

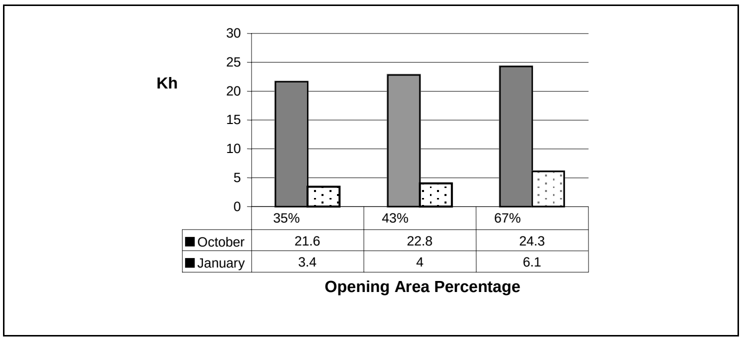


fig 4.9. Histogram of *cooling degree hour* at different opening area percentage on the hottest month (October) and the coolest month (January)

5. CONCLUSION

Passive cooling strategy with natural ventilation system if optimally used at hot humid house will increase thermal comfort of building occupant. Natural air system is an integrated and understanding of environment condition, building and opening. One aspects of opening is opening area percentage, but that aspect also influence other aspects, like ventilation system, room volume and opening position.

Optimum opening area percentage of the three model is 43%. That is because even air change volume is big but overheating period and cooling degree hour value is not big. Increasing opening area from 35% to 43% brings proportional increasing of air change per hour, but increasing opening area from 43% to 67% brings insignificant increasing of opening area.

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