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The Study Of a Market Building Design Concerning The Thermal Comfort Improvement

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Abstract

Market building is a place where people fulfil their daily needs with affordable price. To meet the required price, the overhead of the building service must be low and the consequence is the building will not be equipped by air conditioner to lower the indoor temperature. This research is to study the occupant's thermal comfort in Market building and to study the building thermal comfort (Effective Temperature) for thermal comfort improvement. The study was conducted at Pasar Santa, Jakarta, Indonesia which was built in 2006 and its design is recommended to be a model of today's market building by the local government. The result of this study is the building needs modification to get more air velocity for obtaining better thermal comfort. The simulation of PV electricity for the building is also conducted to know its influence to the overall electricity demand, and the result is PV electricity can cover the electricity demand.

Keywords: market building design, thermal comfort improvement, effective temperature, air velocity, PV.

1. Introduction

Building as an architectural form should address as a reservoir for people to do their activities comfortably, such as providing optimal climate in the interior of the building. Optimum interior climate is one of the main functions of a building (Hiller and Leaman,1976) and it is also as primary functionality that means as the utility value or effectiveness of a product (Dirken,1972). Building has to be capable to achieve good interior climate, beside as form of beauty and status. Moreover, the aspect of indoor thermal comfort is a term of "Physical Quality", part of "Technical Quality" category, for archtectural programming (Van der Voordt and Vrielink,1987)[1].

A market is a place where people fulfill their daily needs, from groceries to garments and market is important not only for low income society but also more for low income seller. On the other hand, currently market is being left by the buyers because market building commonly known as a hot and oppressive building [2]. This evidence is hard to be avoided because the building is not equipped by airconditioner to lower indoor temperature. Large amount of electricity will need to be supplied if the building should furnish airconditioning, which can affect to the selling price and rental space. To this reason, "low overhead cost" is necessarily be taken into account in designing market building. Yet optimum indoor thermal comfort is necessarily to be provided as the sellers need to serve comfortably. It also to give comfort environment for the buyers.

This study is to observe the occupant's thermal comfort in doing shopping and the Effective Temperature of market building,and is also to analyse the design and the improvement of indoor thermal comfort as well as to simulate the PV electricity, as an alternative energy, in order to know its influence to the overall electricity demand.

1.1 Case Study

Fig.1. The map of Jakarta, Indonesia.

The case study of this research is Pasar Santa (*Pasar means: Market*). The building has just been renovated in 2006. The building has three level: Semi Basement, Ground and First Level. This market is located on Kebayoran Baru, South Jakarta, Indonesia (Lat 6.233 Lon 106.8) (See Fig.1). In this region the average temperatur is 27,7°C, the humidity is 71 and the wind speed is 5,43 m/s per year [3].

Pasar Santa is in the Category of ”C Class” market, it means market building is in the housing neigbourhood and it is built on 8.491 m2. It consists of 1.942 shops include 1.269 close shops, 53 counters and 620 open shops.

Fig.2.Pasar Santa (Santa Market Building)

2. Methodology

The research is focused on the measurement of Effective Temperature (ET) of the building, the occupant's thermal sensation, simulation of air speed in the interior, simulation of airspeed adjustment, physical modification and simulation of PV electricity.

The research was conducted on September 2007. In that month the average temperature was around 28,2°C, the wind speed was around 4,5 m/s and the humidity was 68 [4].

2.1 ET Measurement

The ET measurement is based on the data of room temperature, humid temperature, humidity and airspeed. They were measured by 4 in 1 Environmental Tester Lutron LM-8000 Type K. The equipment is a combination of anemometer, thermometer, hygrometer dan lightmeter and it has been certified by UKAS Quality Management ISO 9001:2000 SGS. The collected data then mapped into the Psychomatrick chart and ET Nomogram to get the ET grade (score)[4].

The measurement was conducted by dividing each level of the building into nine zone (See Fig.3). Each zone was identified as the research variables above. The ET and occupant's thermal sensation measurement was conducted three times a day, in the morning (08.00-09.00 AM), noon (11.00-01.00 PM), afternoon(04.00-05.00 PM).

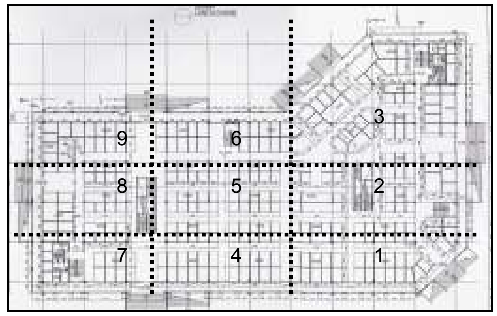


Fig 3. Zones sub division, Ground Floor

2.2 Thermal Sensation Measurement

The occupant's thermal sensation was analysed by using the ISO 7330 ASHRAE. The datas was taken by the use of quitionares to obtain primary data.

The collected data then was calculated by SPSS version 12 program to see the average grade of the occupant's thermal sensation. The results is compared with the thermal comfort scale for Indonesian people as mentioned on SNI T-14-193-03[5]. The scale was classified into three stages:

1. Cool Comfort : ET : 20,5˚C - 22,8 ˚C
2. Optimal Comfort : ET : 22,8˚C - 25,8 ˚C
3. Warm Comfort : ET : 25,8˚C - 27,1 ˚C

At this research the occupant's wore clothes that have an insulation rate around 0,4 Clo and the metabolic rate are around 1,9 MET for the seller and 2,0 MET for the buyer.

The measurement of ET and occupant's thermal sensation was conducted at the same time at each zones. And every measurement employed different respondents.

2.3 Building Design Study

The research variables of the building form in relation to the ET and the occupant's thermal sensation are: the ventilation system, the ceiling's high and the plans sub division. The other variable are sun path and the outdoor condition.

2.4 Air Velocity

Computer simulation is used to analyze the area that lack of air speed. The assessment of airspeed adjustment was also conducted to simulate the lower of ET score. The variables are: effective temperature, room temperature and humid temperature by mapping to the Psychomatric chart and Nomogram ET[4].

2.5 PV Simulation

PV electricity product simulation

The PV electricity product is simulated using only some existing climate and building data and functioned as rough and comparison result to the real PV electricity product. It is also without PV installation price consideration. The real product should be calculated directly on site. Although it's a rough calculation, the simulation result shows the PV electricity potential for the building as an alternative electricity energy source. The calculation simulation was focused on the mono or polycristalline PV panel installed on the roof. The panels are considered as roof materials and cover almost all horizontal surface of the roof. It used the simple PV product equation (in Standard Test Condition 25º C) :

1. $E = G_d \times A_m \times n$ [6]

   E = Electricity product
   G_d = The daily global solar radiation on horizontal surfaces in Jakarta, Indonesia
   A_m = The PV surface area in m^2
   n = The PV cell efficiency = 0,1

2. During their work the PV panels produce heat and also are heated by the solar radiation. Therefore the following equation shows the electricity production in a certain surface temperature [7] Based on Brockhaus the horizontal surface temperature in Jakarta can reach up to 77º C during the day [8]. The Standard Test Condition (*STC*) For PV panel is 25º C. The actual product equation then is :

   $E_t = E \times g$

   E_t =The PV electricity product in t surface temperature (t=77º C)
   g =The reduction factor for tº (77º C) . For Jakarta is = 0.792

3. The Results: Thermal Measurement, Building Design Study, Air Velocity and PV Simulation.

3.1.Thermal Measurement

Based on the analysed assessment, it can be explained as follow: generally the ET score on the Semi Basement floor was the highest, it was 27,44°C and then the First Floor with 27,4°C and the lowest was the Ground Floor with 27,38°C. The ET score in the morning in general was between 26,5 – 27°C. But in the noon and afternoon the overall ET score can reach up to 28°C. From the assessment, the ET condition in the morning corresponds to the category of Warm Comfort (SNI T-14-193-03). On the other hand, in the noon and afternoon the ET score was over the scale of SNI thermal comfort.

The thermal sensation of the occupants, based on the SPSS evaluation, was 81,7% slightly felt to cool-neutral at the ET score of between 26,1-27,5°C. This condition occurred only in the morning. In the noon and afternoon the thermal sensation condition was only around 50-60% of the occupants who vote comfort, except at Ground and First Floor. At those areas about 80% of the occupants felt thermally comfort. Generally, the ET score at those time was more than 27,5°C (see Table.1).

Table 1:

TIME	ET °C	Floor	Number of Responden	Thermal Sensation
08.00 - 09.00 AM	26,7 - 27,1 ˚C.	Semi Basement	29	90 % respondens vote slightly cool-neutral
	26,8 - 27,6 ˚C.	Ground	24	91 % respondens vote slightly cool-neutral
	27,1 - 27,5 ˚C.	First	13	92 % respondens vote slightly cool-neutral
	27,5 - 28,1 ˚C.	Semi Basement	20	Only 50 % respondens vote slightly cool-neutral.
	27,5 - 27,8 ˚C.	Ground	25	Only 36 % respondens vote slightly cool-neutral.
	27,4 - 27,6 ˚C.	First	20	40 % respondens vote slightly cool-neutral.

04.00 - 05.00 PM	27,4 - 28˚ C	Semi Basement	22	Only 77 % respondens vote slightly cool-neutral.
	27,3 - 27,5 ˚C	Ground	19	90 % respondens vote slightly cool-neutral.
	27,4 - 27,7 ˚C	First	15	90 % respondens vote slightly cool-neutral.

From the SPPS, it also can be explained (see Table.2) that, firstly the ET of the building relates to the occupant's thermal sensation with significancy rate of <0,1, secondly it can be interpreted that the ET affects the occupant's thermal sensation of around 5,2% and thirdly it can be read, from Beta value, that if the ET incline about 0,5°C* the thermal sensation condition will be better about 22,8%.

** 0,5 °C = is the range of the tempature test used for SPSS analyse.*

Tabel 2: The regression of ET and Thermal Sensation.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.228(a)	**.052**	.047	1.083

a Predictors: (Constant), ET condition

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	**Sig.**
		B	Std. Error	**Beta**		
1	(Constant)	1.078	.352		3.061	.003
	ET Condition	-.304	.095	**-.228**	-3.188	.002

a Dependent Variable: occupant's thermal sensation.
Source: Primary Data, 2007.

3.2.Building Design Study

Result from design analyses according to the ET score at each zone can be seen as follow:

Tabel 3: ET Score at each zone.

No.	**ET (°C)**	**Zone and Floor**
1	27,23	Zone 1 Semi Basement Fl. Zone 1 Ground Fl
2	27,26	Zone 3 Ground Fl Zone 7 Ground Fl
3	27,33	Zone 2 Ground Fl Zone 5 Ground Fl Zone 7 Ground Fl Zone 8 Ground Fl Zone 9 Ground Fl
4	27,36	Zone 3 First Fl Zone 5 Ground Fl Zone 7 Semi Basement Fl Zone 8 Semi Basement Fl
5	27,4	Zone 2 Semi Basement Fl Zone 1 First Fl Zone 4 Ground Fl Zone 8 Ground Fl Zone 9 Semi Basement Fl
6	27,43	Zone 4 Semi Basement Fl
7	27,46	Zone 2 First Fl Zone 6 First Fl
8	27,53	Zone 3 Semi Basement Fl
9	27,56	Zone 4 First Fl Zone 5 Semi Basement Fl Zone 9 Ground Fl
10	27,63	Zone 6 Ground Fl
11	27,66	Zone 6 Semi Basement Fl

Zone which has the lowest score is Zone 1 at the Semi Basement and Ground Floor (see Fig.4)

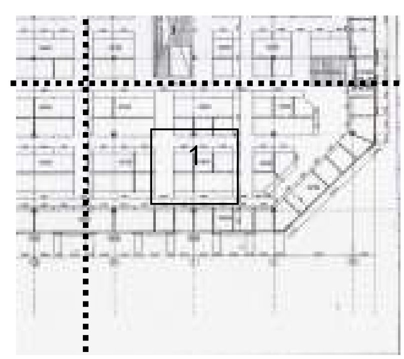


Fig.4. Zone1 Ground Floor

Zone 1 on Ground floor has the characteristics: the opening is a wide corridor surrounding the building envelope and the wide is two meters. There is space, about 60 cm, between the top of the shops and the ceiling that allow air or wind to flow through. The height from base to the ceiling is 4.50 meters. Space between corridor is 2.00

meters. The entrance is a wide opening with 4.00 meters wide and its orientation is SeaWest. On the Semi Basement Floor, the shops are mostly open shops therefore the air can flow straightforwardly. The outdoor is surrounded by tress.

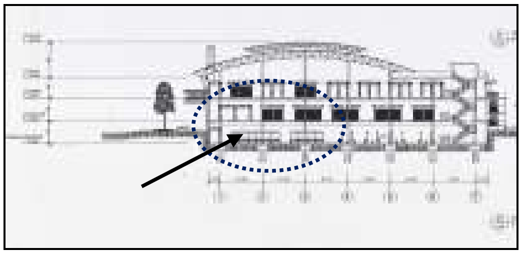


Fig 5. Section of Zona 1 Semi Basement and Ground Floor

The zone with the lowest ET score is zone 6 at Semi Basement Floor (see Fig.7). The zone is opposite to zone 1 which has the highest score of Effective Temperature.

The zone 6 plan contains close shops, the corridor between the shops is around 2.00 meters (see Fig.7,8). The entrance is a wide opening with 4.00 meters wide and the orientation is South. The actual outdoor condition is an open space with no vegetation .

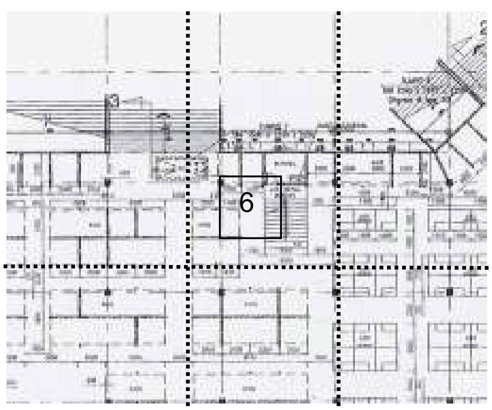


Fig 6. Zona 6 Semi Basement Floor

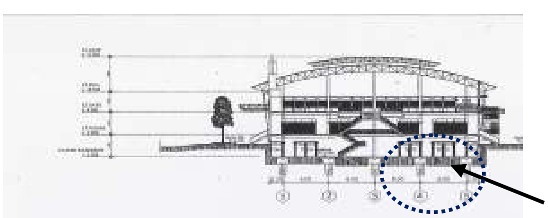


Fig 7. Section Zona 6 of Semi Basement Floor

3.3 Air Velocity

Based on computer simulation, zones that have lacks in airspeed are zones which in the middle of the building.

Fig 8. Zones with lack in airspeed

4. Thermal Improvement

Based on SPSS, the thermal sensation will be better at 22,8% if the ET score decrease 0,5°C, therefore to improve the thermal comfort condition is by adjusting the airspeed. This improvement is corresponding to the theory of Convection. Cooling strategy via the air speed is to move heat.

4.1. Airspeed Adjustment Calculation

From the airspeed adjustment calculation, generally the zones which has the lowest air speed are zone 5 and Zone 6 at each level, especially at Semi Basement level. The airspeed adjustment for these zones generally between 0,8-0,9 m/s.

The overall airspeed adjustment for this building is around 0.45-0.9 m/s. From that adjustment the overall room temperature can be decreased up to between 1.5-1.8°C and humid temperature can be decreased to around 0.2°C. The Effective Temperature also decrease between 0.5-1.1°C.

4.3 Modification

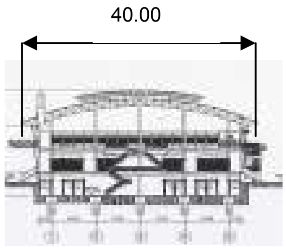
To minimize high occupant's thermal sensation and to improve thermal comfort, the building can be furnished by roof ventilator and exhaust fan. There are some roof ventilators which do not need electricity. This equipment can help "convection process". However, the exhaust fan need electricity to operate but it does not need as much as Air conditioner. Furthermore, based on Effective Temperature measurement, that equipment can be functioned only at noon and afternoon.

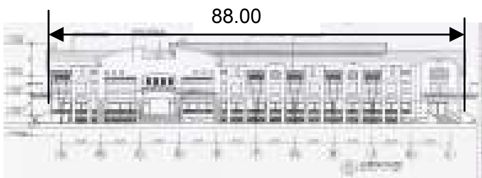
4.4 PV Simulation

Building existing data and the simulation

Total roof surface area : 40 m x 88 m = 3520 m^2
Total net roof area for PV : 80% asumption) =
80% x 3520 m^2 = 2816 m^2
Maximum electricity power installed now = 525 kVa = 525 kW[9]
Stores daily open from 10.00 am to 7 pm [9].

Global solar radiation on horizontal surface for Jakarta in June 3.85 kWh/m^2·d [10].
Global solar radiation on horizontal surface for Jakarta in December 3.62 kWh/m^2·d.[10].





E in June = $G_d \times A_m \times n$
= 3.85 x 2816 x 0.1
= 1084.16
E_{77} = 1084.16 x 0.792 = 858.65 kWh/d

E in December = $G_d \times A_m \times n$
= 3.62 x 2816 x 0.1
= 1019.39
E_{77} = 1019.39 x 0.792 = 807.56 kWh/d

The results show that the PV electricity product in June and December are much above the power installed in the building (858.65 kWh/d and 807.56 c kWh/d compared to 525 kW).

5. Conclusion

The study of market building design concerning on Thermal comfort improvement can be concluded that the occupant's thermal comfort in doing shopping and selling is in between 26,1-27,5°C of Effective Temperature.The occupants will feel uncomfortable if the Effective Temperature is more than 27,6°C.

Influence of The Effective Temperature to the occupants is 5,2% and if the ET fall 0,5°C the occupant's thermal sensation will be 22,8% better.

Cooling strategy to modify the interior thermal comfort is by adjusting the airspeed. From the calculation, the building needs more airspeed between 0,45 – 0,9 m/s. This adjusment can reduce the ET between 0,5 – 1,1°C and with this reduction the occupant's thermal sensation will be between 22,8%-45% better.

To modify the indoor thermal comfort the adjustment of airspeed can be conducted, such as providing roof ventilator or exhaust fan.

PV electricity produced in June and December are much above the power installed in the building (858.65 kWh/d and 807.56 c kWh/d compared to 525 kW).

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