THERMAL PERFORMANCE OF WIDE SPAN MIDDLE-RISE BUILDING IN SURABAYA (CASE STUDY: GEDUNG G ITATS)

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ABSTRACT

Global warming and increase of energy consumption issues has encourage architect to design energy efficient building. The most crucial aspect in designing building in warm humid climate is solar irradiance and wind flow. High level of irradiance increase heat gain of the building and it also cause a higher cooling load and cooling energy. More compact the building form, the cooling energy consumption will be less. Compact or bulky building usually consume less cooling energy than the slim one because it has lower s/v ratio. Thus the bulky form, middle rise wide span building usually use atrium to help distribute daylight in to every room of the building. Unfortunately the daylight from the atrium brings considerable heat because the solar radiation that hit the horizontal plane is very high and it's very difficult to minimize solar gain in the roof. This research aims to evaluate the energy performance of middle rise wide span building in Surabaya. Case study of this research is Gedung G Institut Teknologi Adhi Tama Surabaya

This research use simulation method with ecotect 2011. Sample of middle-rise office buildings in Surabaya were taken randomly. Simulation was conducted to predict energy performance for cooling at a year. Energy performance of the buildings were found to bear some relations to composition of fenestration and opaque roof in atrium.

Keywords: Atrium, Cooling Energy, Energy Efficient, Middle-rise.

A. INTRODUCTION

According to Green Building Index 2010, 60% of energy use in a building allocated for cooling energy and 55% of heat transfer was heat from building envelope. Architect can save the operational energy of the building with a good design that concern the environment and climatically responsive. High solar irradiance in tropics being a challenge for architect to build a comfortable building with low energy consumption. Building façade and roof should be designed to minimize the heat gain in to the building.

Yeang (1996) and Baker (2005) said operational energy in a building can be reduced if the building has a good design. Right choice of building materials, proper form, appropriate location and site planning will reduce the heat gain of the building moreover the cooling load and cooling energy. Envelope design of tropical building should be careful because architect better design room with daylight and good air circulation, on another hand daylight and air circulation in to the building may also cause heat flow in to the building. Gaining heat in the building mens increasing cooling load and cooling energy.

Knowles (1981) said one of factor overheating external façade caused by domination of fenestration surface on building envelope. Most of fenestration surface such as clear glass, fiber glass, polycarbonate, usually have a great U-value and the decrement factor of that materials almost 0, it means that materials receive a lot of heat from environment and transmit almost all that heat in to the building.

By previous research octagonal building consume less cooling energy consumption than other shape such as rectangle, square, L shape, H shape, etc in the same volume (Laksmiyanti 2015). Craford (2011) also says more compact the building, energy consumption will be less. Compact form has less surface to volume ratio which is mean less heat transfer from building envelope and heat gain. Trouble in bulky building is distribution of the daylight. Natural lighting can't achieve the middle of the building even though there's a huge window in the perimeter area. Yeang (1996) suggest to put an atrium to solve this problem. Skylight on the atrium let the sun light came into the middle area of the bulky building so the daylight can be evenly distributed (Heerwagen, 2004). In warm humid area envelope design has a big contribution in thermal comfort, visual comfort, and energy consumption (Markus & Moris, 1980), so it will be necessary t think about façade and roof design.

B. LITERATURE STUDY

Energy Effcient

Lechner (2007) devided operational energy in to three groups: Heating, cooling, and lighting energy. That kind of the most common energy use in building. In warm humid country we don't need heating. Hilmawan (2009) said for commercial building operational energy divided in to 4 groups such as Cooling energy, Lighting energy, Transportation and energy for electrical equipment.

Cooling energy is the energy used for the air system in a building to achieve the thermal comfort of the building user (Satwiko, 2004).BPPT in Hilmawan (2009) determines the percentage sharing of energy use in office buildings as follows: 47% for air system, 25% for lighting, 22% elevators, and 6% for other equipment. Referring to the energy efficient index, the limit of electrical energy used for cooling is 47% of 200kWh / m2 / year or 94kWh / m2 / year.

Climate and Building Design

According to Szokolay (1987) and Moore (1993) tropical climatic regions have the following characteristics:

1. Cloudy sky throughout the year with cloud cover 40% -80% which can cause glare / glare
2. The sun shines all year long which results in high radiation
3. Very high humidity (40% -90%)
4. The difference in temperature is relatively the same day and night, and warm mean temperature (23^{o}C – 34^{o}C)
5. Low wind speed 1,1m / s - 4,3m / s.
6. High rainfall (1200mm / year)

Solar radiation makes an important contribution to the heat the building receives. Predictions of the average solar insolation (in a day, month or year) are required to calculate the cooling load obtained from radiation that falls on a wall or that penetrates through a window and roof

Solar radiation will cause the temperature to increase and affect the heat that enters the building. According Szokolay (2004) to calculate the amount of heat entering in the building envelope caused by radiation on the wall material is not opaque on one side of the building used the equation:

$$_sQ_{so} = A \times U \times \mu \times \alpha \times Rso \times (G_{t-\phi} - G_{av})$$

with:

sQso = The amount of incoming heat due to radiation on the wall is opaque (Watt/m^2)
A = Area of wall (m^2)
U = U-value (W/m^{2}K)
μ = Decrement factor
α = Absorbtance
Rso = Resistivity outside surface
Gt = Radiation on one side at that time (Watt)
Gav = average of Radiation on one side (Watt)

The translucent wall material usually has a time lag (ϕ), so the amount of radiation seen is several hours before the calculation. For translucent walls, the heat entering the building due to radiation is affected by the glass surface area, alternating solar gain (θa) and the current radiation and average radiation in a day (Szokolay, 2004).

$$_sQ_{sg} = A \times \theta_{a\ x} \times (G_t - G_{av})$$

With:

sQso = The amount of incoming heat due to radiation on the tfenestration wall (Watt/m2)
A = Area of wal (m2)
θa = alternating solar gain
Gt = Radiation on one side at that time (Watt)
Gav = average of Radiation on one side (Watt)

Warm Humid area tend to have high temperatures both day and night. The temperature difference between day and night is not too far away. This temperature has much effect on heat flow by conduction on building envelope. On the wall is not translucent heat magnitude due to conduction is affected by the surface area, U-value, decrement factor, and outdoor average (Szokolay, 2004). The translucent wall has a time lag so that the temperature seen is the temperature a few hours before the calculation time.

$$_sQ_{co} = A \times U \times \mu \times (T_{o.(t-\phi)} - T_{o.av})$$

sQco = The amount of incoming heat in opaque wall(Watt/m2)
A = Area (m2)

U = U-value (Watt/m2K)
μ = Decrement factor
Tot-ϕ = Outdoor Temperature -time lag (°)
Toav = average Outdoor Temperature (°)

On the glass, the current temperature will directly affect the amount of heat coming in at this time also because the glass has no time lag. Glass also has no decrement factor so that the incoming heat is calculated by the equation :

$_sQ_{cg} = A \times U \times (T_{o.t} - T_{o.av})$

sQcg = The amount of heat entered by conduction of the fenestration wall (Watt/m^2)
A = Area(m2)
U =U-value (Watt/m^{2}K)
To_t = Outdoor Temperature (°)
Toav = Average of Outdoor Temperature (°)

C. METHODOLOGY

This research aims to find the most efficient combination of opaque roof and skylight in energy use. Before finding the perfect combination, first building with bulky form was chosen randomly as a case study. Performance of the building was tested for the base case. This paper describes the thermal performance of the case study. Generally it use simulation method.

Simulation with ecotect 2011 used to analyze thermal performance of this building. Independent variable of this research the design of the atrium's roof. Cooling energy, Heat gain and Indoor temperature are kind of dependent variable.

D. RESULTS AND DISCUSSION

Surabaya Climate Condition

Based on the meso climate data, According to the data of meso climate in Surabaya, temperature of Surabaya is quite high. There's no outdoor condition which is in the comfort zone (fig 1.). Neutral temperature of Surabaya is 26.1°C so the upper and lower limit for thermal comfort in temperature in between 24.1°C – 28°C. in hottest day, almost all day the temperature in above the upper limit (fig 1.).

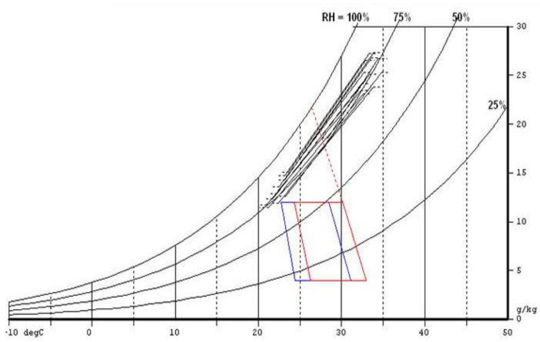

Figure 1. Psycrhometric chart Surabayain last 5 years
(Source: Archipak)

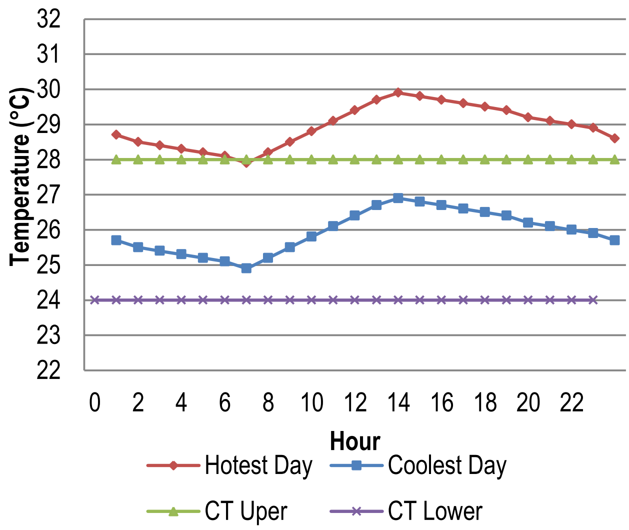

Figure 2. Outdoor Temperature
(Source: Ecotect)

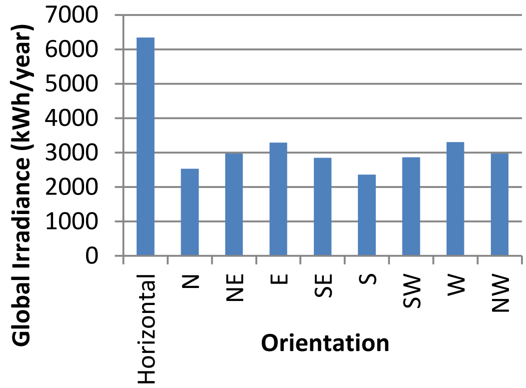

Figure 3. Outdoor Temperature
(Source: Archipak)

Thermal comfort also depended on global irradiance and humidity. Tropical climate has high amount of solar radiation. Figure 3. describe the amount of global solar irradiance at all orientation in Surabaya. The highest radiation comes at horizontal plane. It means building with high area of roof supposed to be aware about the roof design and material to minimize the radiation which is transmit to the building.

Condition of Gedung G ITATS

Gedung G ITATS is one of 4 storey building in Institut Teknologi Adhi Tama Surabaya with bulky appearance and having atrium on it. Ground floor of this building use for administrative room. 2nd up to 4th floor of this building use for classroom. Figure 4.show the typical floor plan of this building. Operational time of the building from 8.00 am – 10.30 pm in weekdays and off in weekend.

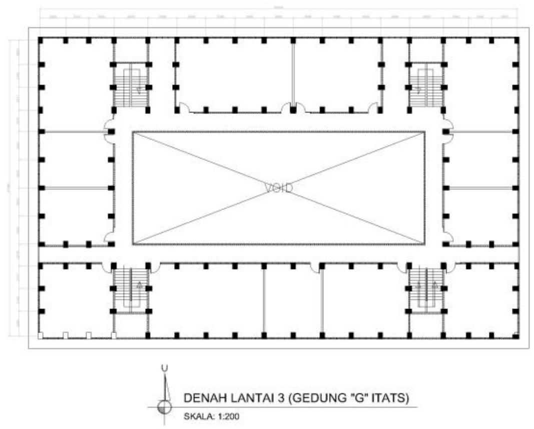

Figure 4. Floor plan of Gedung G ITATS
(Source: Laksmiyanti)

Cooling Energy and Heat Flow in Gedung G ITATS

Total cooling energy consumption in gedung G Institut Teknologi Adhi Tama Surabaya in a year is 407.4 kWh/m^2/Year (Tabel 1.), it's way too far from the standart. Energy efficient building suppose to consume total operational energy less than 200kWh/m^2/Year. According to SNI in Hilmawan (2009), maximum percentage for Air conditioning system for office building is 47% or equal 98kWh/m^2/Year

Total energy use at ground floor is lower than others because this floor has smaller room and it is an administrative room which is operate 8 hours a day during the weekdays and off in weekend. Moreover there are a lot of tree around the building which also shade the building and reduce the direct and indirect radiation heat gain in to this building. This building has no ceiling, and no insulation in the roof. The classroom covered by concrete roof and the void covered with galvalum and polycarbonate. Galvalum, polycarbonate and concrete has high conductivity so the conduction heat gain in the 3rd floor of this building is higher than others. Ceiling can use as insulation because plafond and cavity between concrete and plafond can block the heat by the convection.

Tabel 1. Total cooling energy of model in a year

MONTH	COOLING ENERGY (kWh/m²)				TOTAL COOLING ENERGY (kWh/m²)
	Ground floor	1st floor	2nd floor	3rd floor	
Jan	4.2	9.0	9.2	10.3	32.8
Feb	3.6	7.4	7.5	8.7	27.2
Mar	4.2	9.9	10.1	12.4	36.6
Apr	4.1	10.6	10.9	13.0	38.5
May	4.1	10.7	11.0	12.9	38.7
Jun	3.7	8.3	8.6	9.6	30.2
Jul	3.7	7.8	8.0	8.8	28.3
Aug	3.4	5.9	6.0	6.3	21.6
Sep	3.8	7.6	7.8	9.1	28.3
Oct	4.4	11.8	12.1	15.2	43.6
Nov	4.3	10.9	11.1	13.4	39.7
Dec	4.7	11.5	11.7	13.8	41.7
Total	48.2	111.4	114.1	133.7	407.4

Great amount of cooling energy in this building caused by a great heat gain into the building. Most het gain comes from transfer by conduction (fig 5.). sQc is conduction heat flow, it's heat flow from that building envelope which is occur 24 hours. To minimize the sQc we should design the wall and roof carefully. Too many window in the wall, too large fenestration roof in atrium, high u-value of opaque wall and roof can caused the increase of the conduction heat gain.

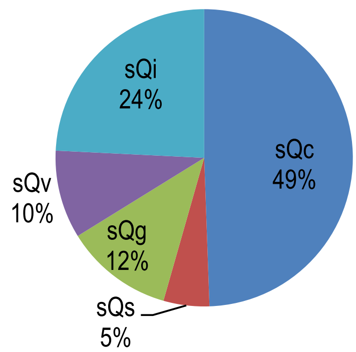

Figure 5. Heat Gain Breakdown of Gedung G ITATS
(Source: Laksmiyanti)

sQi is the second highest from that diagram. sQi means internal heat gain, heat which is come from electricity and activity in the building. Electricity in this building is divided in to three groups: Lighting, Air Conditioning, and electrical equipment. Thus long operational hours, internal heat gain of this building increase. Wrong design of the window also being next factor of increasing sQi. Actually, there is no window in this building, only fenestration wall. No windows means no air flow, and wide area of fenestration wall make the heat which is transmit to the building well be remain and increasing over and over again because there is no way of air flow to bring the heat out. The only way to create thermal comfort in no window building is use air conditioning system. It means increasing of power consumption and internal load.

The 3rd highest heat gain in this building is radiation heat gain. Radiation gain divided in to two:

1. Direct irradiance heat gain (sQg) is the radiation which is comes and transmit directly to the building. Usually this type of heat flow occur in transparent wall and roof.
2. Indirect irradiance gain (sQs) is the radiation heat gain trough opaque surface. The solar radiation hit the opaque surface, and there some of it reflected and absorbed. The absorbed heat will be transmit to the building in a while depend on the time lag of the materials.

In this building sQg is so much higher than sQs. There are a lot of solar radiation transmit into this building from the fenestration surface. This atrium has 50% skylight, it makes high quantity of direct irradiance transmited. To make it lower, the composition of transparent surface should be reduced.

sQv is ventilation gain. Heat gain which is enter the building through air flow of the building. This building has no window doesn't mean has no air flow at all. All room use air conditioning which is usually has 2 Air Change per Hour, so the ventilation gain of this building comes from this air flow. This building use full air conditioning, that's why the ventilation gain of the building quite low.

Hourly Heat Flow in Gedung G ITATS

Indoor temperature in this building starts increasing in 8.00.am and decrease after sunset, after the direct irradiance being zero (fig. 6.). According to that graphic the increasing of indoor temperature at that time caused by the increase of direct irradiance gain in the same time. Indoor temperature keep increasing till 18.00.pm because there's delay heat gain through opaque component. To reduce sQs adnd sQg in this building, architect can reduce the transparent surface. Designing the shape of atrium could be a good alternative to reduce the direct irradiance gain.

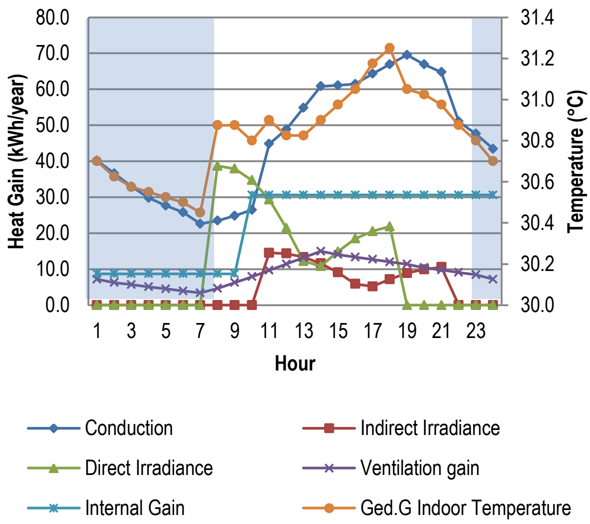

Figure 6. HourlyHeat Gain of Gedung G ITATS
(Source: Laksmiyanti)

High conduction flow in this building caused by the huge area of material with high U-value. Tabel 2. and 3 describe the thermal properties of opaque and fenestration material inthi building. Using metal roof with no insulation is a bad idea. Change the materials with lower conductivity can cut the amount of conduction heat flow.

Tabel 2. Thermal Properties of Opaque Materials

	Brick Plester	Concrete	Galvalum
U val	3.0	0.9	7.14
admittance	4.1	2.3	7.1
T lag	2.9	7.0	0
Dcr factor	0.8	0.6	1
abs	0.3	0.9	1

Tabel 3. Thermal Properties of Fenestation Materials

	Clear Glass	Poly-carbonate
U val	6.00	5
admittance	6.00	5
Sgf	0.80	0.78
Asgf 1	0.64	0.38
Asgf 2	0.47	0.47
SC	0.93	1

E. CONCLUSION

Thermal performance of gedug G Intitut Teknologi Adhi Tama Surabaya is awful. too many fenestration surface in the wall and roof make the heat gain increase rapidly. Instead of saving energy by reduce the lighting energy,put a wide opening causing the high irradiance and conduction heat flow. Unfortunately total energy consumption for cooling is higher than lighting energy which is wanted to save.

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