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Characteristics of Glass Materials that Influence the Level of Thermal Comfort and Building Energy Consumption

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Abstract. Energy requirements are increasing rapidly. The building sector is one of the world's largest energy consumers. The proportion ranges from 10-15 percent in developing countries and more than 40 percent in developed countries. Building is designed to accommodate human activities should apply designs that are able to minimize the amount of energy consumption during the construction process and when the building is operating and occupied. The simulation process in this study was computerized with the help of the main software used was EnergyPlus v8.1 and version 0.7 of Open Studio plugins that were run on Google Sketchup v7.0 software. Simulation was only conducted on one typical floor in the position in the middle of the total height of the building. The dimensions of this hypothetical floor are 40m x 40m with floor to floor 4.2 m height and floor to ceiling 2.8 m. This model is expected to represent the typical office building. The amount of energy consumption in this building is indirectly derived from the design of the building envelope. The results of this study indicate the greater the value of Solar Heat Gain Coefficient (SHGC), the greater the heat radiation from sunlight that will enter the building / room. The results showed that higher temperatures in the room led to the higher energy consumption in the building. Every decrease in SHGC is 0.2 led to an increase in energy consumption by approximately 9 kWh / m^2. In addition, to achieve the thermal comfort of occupants by doing a decrease in room temperature settings it will also have an impact on the amount of energy consumption. The increase in energy consumption of each Air Temperature is lowered by 1 ° C by 3.44 kWh / m2.

Keywords: Glass, Building Envelope, SHGC, Thermal Comfort, Energy Software Simulation

INTRODUCTION

One of the sectors that has been the biggest energy consumer in addition to the industrial and transportation sectors is the building sector. However, we can actually reduce the huge energy needs if we are able to apply development concepts that are adaptive to the environment and economical in energy use.

The comfort factor when inside a building is one of the important aspects that must be achieved. The comfort can be achieved by the building itself (passively) or by using energy resources (actively). The most important factor is thermal comfort considering that thermal behavior is very influential on energy use, and one of the ways that can be taken is through the design of the building which is the responsibility of the architect [1].

In addition, the buildings are designed to accommodate human activities. It should apply designs that are able to minimize the amount of energy consumption during the construction process and its operational hour. If an architect does not pay close attention to the building material during the design phase, it actually has a fatal effect on the level of thermal comfort of the occupants as well as the size of the building's energy consumption.

Thermal comfort in space certainly cannot be separated by making the temperature indicator as a benchmark. The actual indicator that must be considered in achieving the comfort level of humans inhabiting the space is the Operative Temperature value. The operative temperature is the average value of the sum between air temperature and mean radiant temperature. It is the temperature directly felt by human skin [2].

High-rise buildings that use artificial ventilation only pay attention to air temperature in the cooling system / HVAC. Actually, what must be considered in achieving human comfort level is the Operative Temperature value, where Operative Temperature is the temperature that is directly felt by human skin [3].

Previous research that has been done [4] most only consider the thickness and color of the glass and the cooling temperature settings that are not quite right in the building design process. While in this study the details regarding the ability of glass to transmit sunlight radiation into buildings are emphasized. Beside that the temperature regulation on the air conditioning system is also very considered. When referring to the high energy consumption in high rise buildings in Indonesia, it can be concluded that one of the causes is the building design process which is not appropriate both physically the building (building envelope) and the electrical mechanical design. The results of this study are expected to provide input to the government, especially those that focus on reducing energy use in Indonesia to support government programs in terms of reducing energy use, especially from the building sector. Moreover, especially architects and engineers to provide input and new knowledge in terms of designing buildings and can be a reference in the process of planning and designing buildings in accordance with the comfort level of the occupants as well as friendly to current environmental conditions.

METHODOLOGY

This research used simulation method through computer models. The simulation process in this study was computerized with the help of the main software used was EnergyPlus v8.1 and version 0.7 of Open Studio plugins that were run on Google Sketchup v7.0 software. Other software used outside the main software is a text processing application 31 Notepad ++ for mass editing large numbers of IDF files before they are simulated, and Microsoft Office Excel for processing numerical data from simulation results.

Simulation was only performed on one floor in the middle of the total height of the building. Simulations of single floors with multipliers were able to provide calculation results that were close to the average of all effects obtained the building as a whole with an error rate of less than 1% provided that the floor is in the middle of the total height of the building, see [5]

When you want to run a simulation using EnergyPlus software, there is a need for climate data used to describe the climatic conditions in which the building is located. Climate data used is climate data with the location of Jakarta. The coordinates used are latitude 6, 2040 LS and longitude 106,8210 BT at an altitude of 10 meters above sea level. The city of Jakarta was chosen because it was considered capable of representing the maximum climate conditions in Indonesia.

Simulation is only done on one typical floor in the position in the middle of the total height of the building. Modeling is only done on a typical floor because in order to know the condition of the average temperature and energy of each floor in high-rise buildings. The dimensions of this hypothetical floor are 40m x 40m with floor to floor 4.2 m height and floor to ceiling 2.8 m. The dimensions of 40m x 40m are chosen because of the average minimum distance of office buildings between the outer walls and 12.5 m cores. The simulated floor is divided into five big zones: four zones of office activities (air-cooled) which are located in accordance with the direction of the wind and one zone of the core in the center of the building (not air-cooled). Each big zone divide into four small zones which aims to determine the level of temperature difference at a certain distance. The office activity zone includes the north, east, south and west zones. The top and bottom floors of the simulated floor will be modeled as adiabatic.

(a) (b)

FIGURE 1. (a) Hypothetic Building Modeling, (b) Hypothetic Building Modeling Floor Plan

Research Variable

The variations in SHGC is determined based on calculated SHGC values from glass products listed in the IGDB (International Glazing Data Base) international glass database. Glass calculation and selection are performed with the LBNL Window v6.3 software. As far as possible, the SHGC value chosen right or close to the planned SHGC variation numbers is 0.2; 0.4 and 0.8

RESULT AND DISCUSSION

Effect of Variation in SHGC on the Mean Radiant Temperature Value

Simulations at this stage examined the effect of variations in building sheaths seen from the hypothetical model of 0 ° orientation and floor plan 1: 1 with a range of variations in SHGC (0.2; 0.4; 0.8) in the fixed WWR conditions (40%) in state of not using shading / shade. The setting value of air temperature (T_a) is constant at 25 ° C). T_{mrt} is the amount of heat released by objects and elements around the room. This condition is influenced by several things, one of which has a large role is the temperature of the wall (surface inside temperature). Surface inside temperature can be seen from Figure 2.

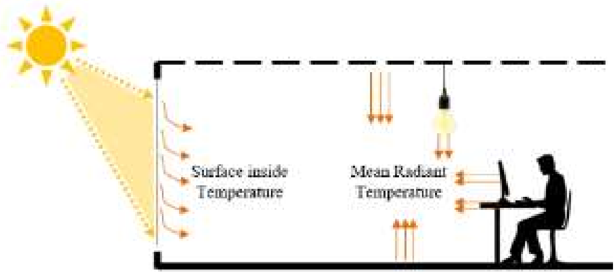

FIGURE 2. Overview of the Elements that Affect the Value of T_{mrt}

Surface Inside Temperature is part of T_{mrt} because it is the value of temperature or temperature inside the walls of the most outside of the building. In this room, it is also assumed that there are general electronic items in an office and use the type of T5 lamp which is also used on average by office buildings.

The surface inside temperature greatly affects the T_{mrt} value. The simulation results obtained are almost the same as the previous simulations, namely the value of the surface inside temperature is higher than the T_{mrt} value at three variable of SHGC (0,2;0,4;0,8).

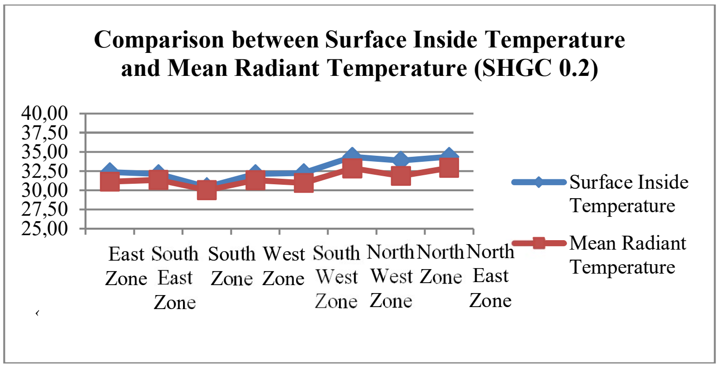

FIGURE 3. Graph of Surface inside Temperature Value and Mean Radiant Temperature at SHGC 0.2

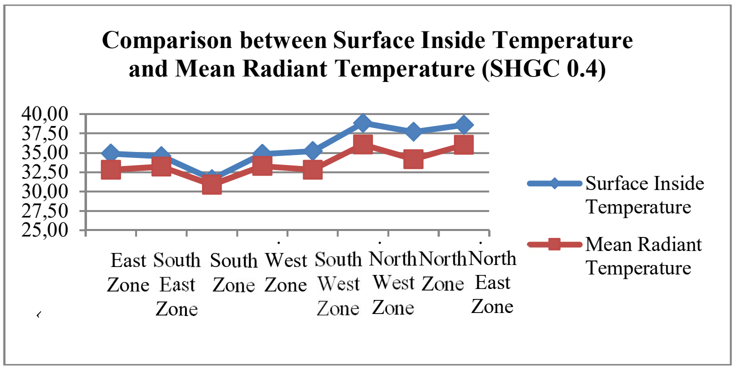

FIGURE 4. Graph of Surface inside Temperature Value and Mean Radiant Temperature at SHGC 0.4

But at SHGC 0.8, the value of Surface Inside Temperature and the T_{mrt} value are almost the same because the amount of incoming solar radiation is 80%, 20% is reflected back. The greater the amount of light entering the surface inside the temperature is large, but the increase in T_{mrt} becomes significant because the heat of the sun which is forwarded in is reflected into the room and increases the T_{mrt} value.

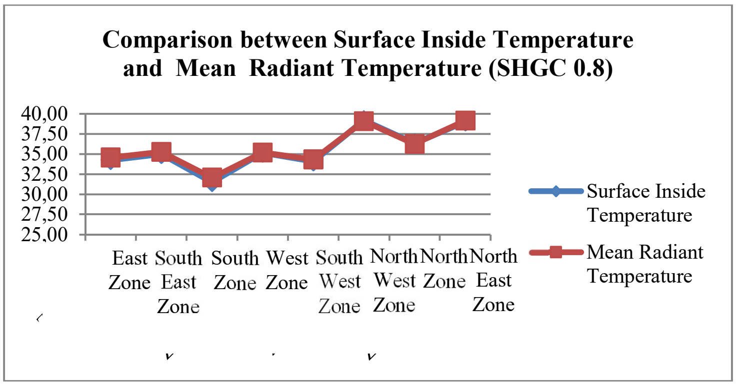

FIGURE 5. Graph of Surface Inside Temperature Value and Mean Radiant Temperature at SHGC 0.8

Next is the analysis of the results obtained by the TMRT value. The simulation results can be seen in Figure 6.

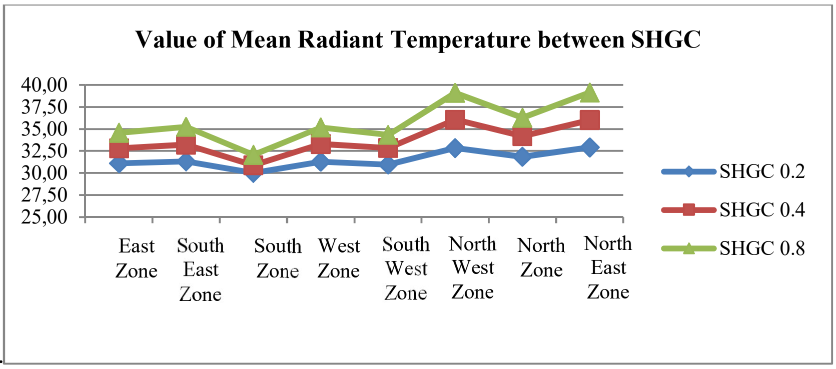

FIGURE 6. Graph of Value and Mean Radiant Temperature between SHGC

The explanation from Figure 3 to 6 can be summarized in the Table 1.

TABLE 1. Comparison of Acquisition of Maximum and Minimum Values Surface Inside Temperature with Mean Radiant Temperature

SHGC	
Surface Inside Temperature Minimum	30.40
Surface Inside Temperature Maximum	39.18
Decrease range *Surface Inside Temperature*	1.2°C-4.5°C
SHGC	
T_{mrt} Minimum	30.01°C
T_{mrt} Maximum	39.09°C
Decrease range T_{mrt}	1°C-3.5°C

Based on the Table 1, it can be seen that the rented average is a significant reduction achieved when carrying out glass type variations (SHGC). The reduction range when varying SHGC can reach 4.5°C in the acquisition of Surface Inside Temperature and 3.5°C in the acquisition of T_{mrt} values.

Effect of SHGC Variation on Operative Temperature Value

In the simulation, to determine the effect of using several types of glass using the SHGC variable indicator, the WWR condition is locked at 40% and the T_a setting is at 25°C. The type of SHGC to be simulated is 0.2; 0.4; 0.8. The increase in the number of SHGC means an increase in the ability of glass to continue radiation of sunlight into buildings.

The simulation results can be seen in the Figure 7. The graph in the picture shows the T_{op} results. The effect of SHGC is shown in the lowest T_{op} value achieved in the condition of SHGC 0.2 which is equal to 28.25°C and the highest gain in the use of SHGC 0.8 is 32.37°C. Any increase in SHGC of 0.2 can increase the T_{op} value by 0.2°C to 1.3°C.

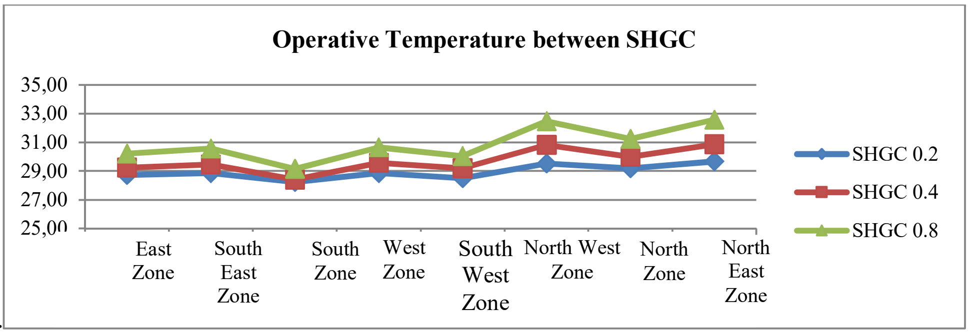

FIGURE 7. Graph of Operative Temperature Value between SHGC

As explained from Figure 7, the greater type of SHGC used leads to the greater amount of solar radiation that can be transmitted into the building. The greater heat which enters the building leads to the greater the results in buildings and the greater energy used to cool the building.

TABLE 2. Table of Acquisition of Energy Consumption among SHGCT Table of Acquisition of Energy Consumption among SHGC

IKE	SHGC 0.2	SHGC 0.4	SHGC 0.8
Lighting	26.58	26.58	26.58
HVAC	49.24	58.48	65.4
Other	28.24	28.24	28.24
Total [kWh/m2]	104.06	113.3	120.22

The following is a table of energy consumption from each variation of SHGC. Every decrease in SHGC is 0.2, it can increase energy consumption by approximately 9 kWh / m2.

Effect of Air Temperature Variations on Operative Temperature Values

Based on the results of the following simulations: the WWR in the range of 30% -65%, SHGC 0.2; 0.4; 0.8; shading with VSA 30, VSA 50, VSA 70, non-shading and setting the air temperature (T_a) which remain at 25°C can be seen that there is no temperature operative temperature (T_{op}) that reaches a comfort value of 25°C according to the standard SNI 03-6572-2001. By knowing this result, a further simulation is performed by making air temperature (T_a) as a variable and changing the T_a setting to reach the T_{op} value according to the comfort value stated in SNI 03-6572-2001 which is 25°C, see [6]. T_a variables used are 20°C, 18°C and 15°C.

In the T_a setting 25°C among the three types of simulated SHGC (SHGC 0.2; 0.4; 0.8) none of them can meet the comfort standard of T_{op} 25°C. Then the Ta setting is simulated to be changed to 20°C, the results obtained on the west wall for SHGC 0.2 and 0.4 are able to meet the comfort standard of 25 ° C. Whereas, the southeast wall only 0.2 SHGC is capable of being fulfilled and none for the northwest wall is able to meet T_{op} standards in space because the results are above 25°C.

When the T_a setting is lowered again to 18°C on the west wall of the entire SHGC variable is able to meet the standard below 25°C. In addition, for the southeast wall only SHGC 0.2 and 0.4 SHGC can be fulfilled. And on the northwest wall only 0.2 SHGC is fulfilled. The next simulation is to reduce T_a back to 15°C. In this simulation for the west and southeast walls as a whole, the SHGC variable can meet the T_{op} 25°C comfort standard. However, on the northwest wall, only 0.2 SHGC is fulfilled. It can be concluded that by decreasing the T_a setting, the selection of SHGC or glass type is quite effective in reducing the T_{op} value, which is in the range of SHGC 0.2 to 0.4. The greater value of SHGC leads to the greater the value of T_{op} because the higher heat of the sun is able to be passed into the room through openings.

The Effect of Decreasing Air Temperature on Energy Consumption Intensity

Based on further simulations, the Ta setting that has been applied to the regulation of the building air conditioning system is not appropriate because the perceived temperature of the building occupants does not reach the standard set by SNI 03-6572-2001 of 25°C. Therefore, it can be concluded that what should be done is by lowering the Ta setting to reach a standard temperature of 25°C. Simulations that change the Ta settings have been carried out by lowering the Ta settings to 20°C, 18°C and 15°C.

With the reduction of T_a to reach the Top temperature according to the standard, it can directly affect the intensity of building energy consumption. The smaller temperature setting T_a, leads to the higher energy consumption of the building. Logically it can burden the building manager, but comfortably it has a very good impact on the occupants of the building.

TABLE 3. Value of Energy Consumption Intensity (kWh / m2) between SHGC based on Decreasing Air Temperature Settings

	SHGC 0.2	**SHGC 0.4**	**SHGC 0.8**
Air Temperature 25	104.06	113.3	120.22
Air Temperature 20	122.51	131.3	136.63
Air Temperature 18	128.3	138.24	142.7
Air Temperature 15	139	147.3	152.87

The following simulation results can be seen from the Table 3. The Table 3 shows the acquisition of energy consumption from several WWR variations with a decrease in T_a from 25°C to 20°C, 18°C and 15°C. The lower the T_a, the more energy consumption will be increased. To see the increasing range of energy consumption from the decline in T_a for some variations of SHGC, it can be seen from the Table 4. From each increase in SHGC by 0.2, the decrease in T_a from 25°C to 20°C increases the range by 16 kWh / m2-18 kWh / m2. In addition, the reduction of T_a from 25°C to 18°C is 22 kWh / m2-25 kWh / m2, and the reduction in T_a is 25°C to 15°C the increase range is 32 kWh / m2-35 kWh / m2.

TABLE 4. Difference in Value of Energy Consumption Intensity (kWh / m2) between SHGC

	Difference IKE SHGC 0.2	Difference IKE SHGC 04	Difference IKE SHGC 0.8	Difference Average IKE	Increase Range IKE (kWh/m2)
Air Temperature 25	18.45	18	16.41	17.62	16-18
Air Temperature 20	24.24	24.94	22.48	23.89	22-25
Air Temperature 18	34.94	34.00	32.65	33.86	32-35

Referring to the level of energy gain and the average increase in energy consumption when the air temperature setting is lowered, it can be seen how much the increase in energy consumption per T_a setting is reduced by 1°C. In the variation of SHGC the value of the increase in energy consumption per T_a is reduced by 1°C by 3.44 kWh / m2. While for shading variations, the increase in value is 3.57 kWh / m2.

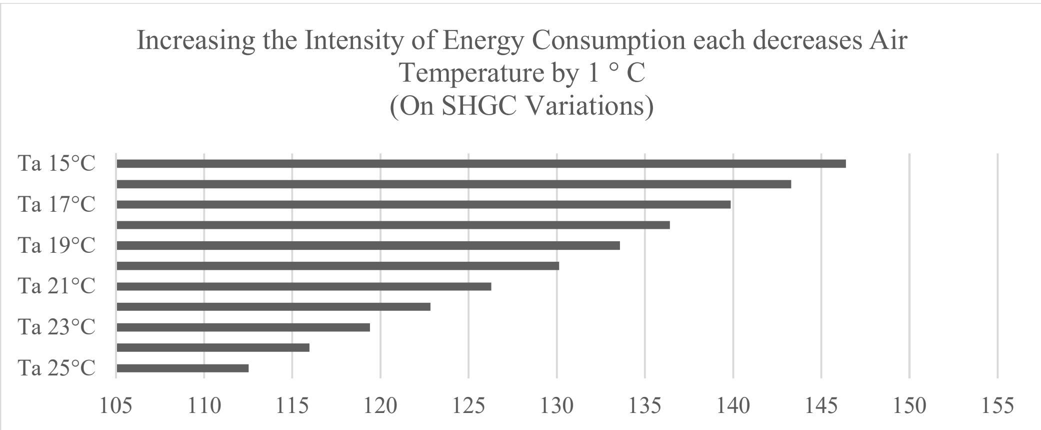

FIGURE 9. Diagram of Increase in Energy Consumption Intensity Each Decrease Air Temperature Setting
Source : Personal Analysis, 2016.

CONCLUSION

When referring to the most effective T_a setting at point 18°C, the characteristics of the building glass material for each orientation are considered the most effective. With the reduction of T_a to reach the Top temperature according to the standard, the lower temperature setting T_a leads to the higher energy consumption of the building. Because the smaller T_a setting causes the greater cooling system effort to cool the room. As a consequence, the energy consumed by the building is greater. When analyzed for energy recovery rates and the average increase in energy consumption, when the air temperature setting is lowered, it can be seen how much energy consumption increases in each T_a setting is reduced by 1°C. In the variation of SHGC the value of the increase in energy consumption per T_a is reduced by 1°C by 3.44 kWh / m2. As explained earlier, the variation of SHGC shows the most effective application when viewed from the large range of temperatures that can be lowered. The variation of SHGC is considered the most effective because the use of small type SHGC (type 0.2-0.4) is sufficient to be able to withstand direct solar radiation transmission and diffuse transmission of solar radiation.

ACKNOWLEDGMENTS

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