ITU A|Z • Vol 15 No 2 • July 2018 • 147-152

Solar heat transfer in architectural glass facade in Semarang Indonesia

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Received: September 2017 • Final Acceptance: May 2018

Abstract

Semarang is a city in Indonesia with humid tropical climate. It stays hot and humid all year round. Ironically, many office buildings in Indonesia, including in Semarang, are beginning to use International Style or Glass Architecture. The sun can penetrate such glass facades, raising the room temperature in the building and thus the energy consumption for air conditioning. With the help of the Simulation Program WUFI-2D, this research provides insights on the amount of solar heat transfer that occurs on glass facades. The result shows that the heat transfer in various types of glass facades significantly increases the room temperature inside the building.

Keywords
Glass architecture, Solar heat transfer.

doi: 10.5505/itujfa.2018.50465

1. Introduction

In countries with humid tropical climate such as Indonesia, is necessary to decrease sunlight penetration in buildings. Sun shading installed on windows functions to limit sunlight penetration and heat increase inside the buildings. Anwari Dananjaya, 2013, examined the tropical architecture facades of office buildings in Jakarta. High rise buildings built between 1970-1990 have relatively good forms of sun shading (see. Figure 1). Santoso, A.K., & I Gusti Ngurah Antaryatama, 2005, analyzed the effect that glass facade in high rise buildings in humid tropics have on energy consumption. They showed that the increase in sunlight, because of missing shading on the facade creates a higher heat transfer and therefore a higher energy demand for cooling. The energy needed to cool the building's rooms far exceeds the energy needed to light the rooms in buildings that use sun shading.

In the study of Gratia E. and De Herde A., 2007, the factors that influence the greenhouse effect in a Double Skin Facade (with glass facade) were identified using a one-dimensional approach under various operative scenarios. By analyzing the global behavior of a building with a Double Skin Facade, they found that the greenhouse effect is quite beneficial to the building en-

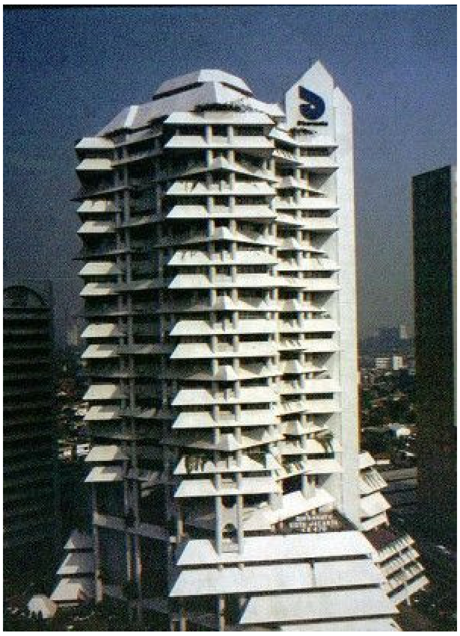

Figure 1. Wisma Dharmala Jakarta, one of the buildings in 1982 with a good forms of sun shading.

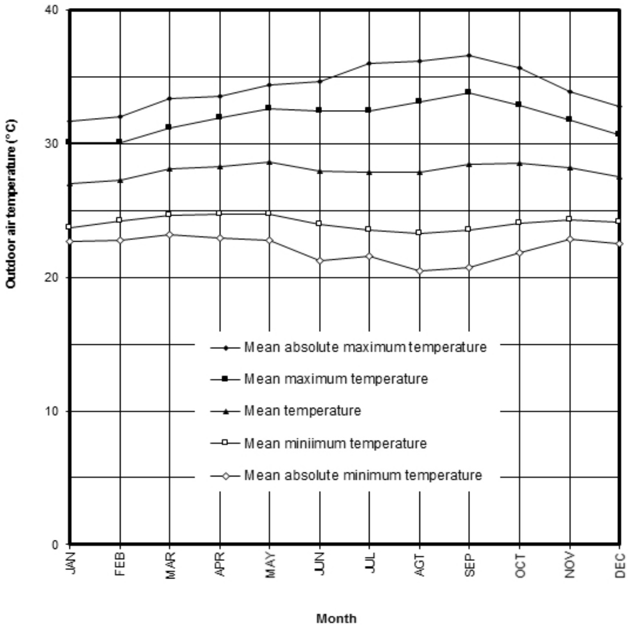

***Figure 2.** Yearly monthly averages of the outdoor air temperature in Semarang in the period from 2000 to 2015.*

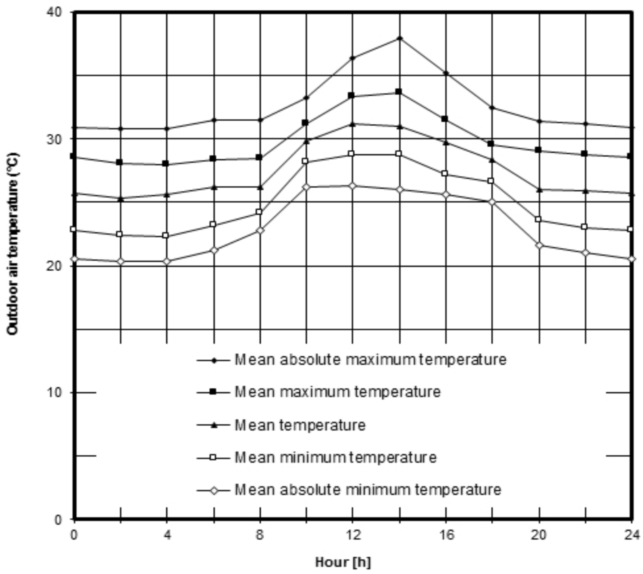

***Figure 3.** Hour by hour daily curve of the air temperature in Semarang in the period from 2000 to 2015.*

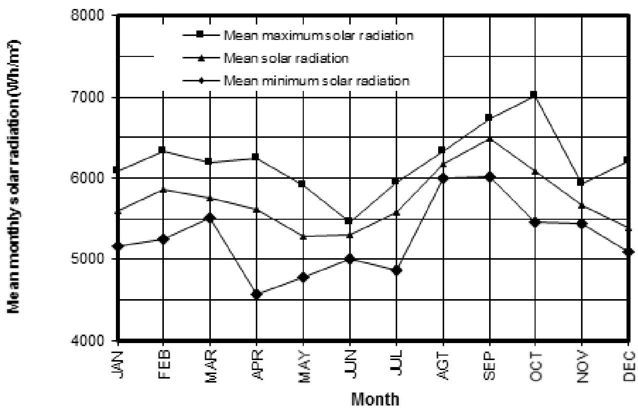

***Figure 4.** The monthly means of solar radiation in Semarang in the period from 2000 to 2015.*

ergy balance. Double Skin Facade is of course applicable to subtropical countries that have four seasons. Research on the effect of glass facades on heat transfer and the thermal comfort in the room, has yet to be conducted for the humid tropics.

A humid tropical climate is characterized by humid and hot weather all year round including both dry and wet seasons. The temperature data in Semarang, Indonesia as the object of observation, is shown in Figure 2 and 3. (Purwanto, L.M.F., 2016)

The Meteorology Climatology and Geophysics Council in Semarang proposed the solar irradiance measurement as shown in Figure 4. The solar radiation in Semarang is considerably high.

The Simulation Program WUFI-2D was used in this research. It required data sources about glass to provide accurate calculation input on the differences between two types of glass used as the objects of observation in Semarang buildings. Table 1 presents the Physical and Mechanical Properties of Glass, while Table 2 shows the Technical Characteristics of Glasses.

Table 1. *Physical & mechanical properties of glass (P.T. Asahimas Flat Glass, 2008).*

Item	Value
Index of refraction	1.52
Index of reflections (vertical incidence)	approx. 4% at each surface
Specific heat	837.36 J/kg K (273K-323K)
Heat Distortion Temperature	720°C – 730°C
Thermal Conductivity	0.79084 W/mK
Thermal Expansion Coefficients	8.5 – 9 x 10^{-6} /°C (normal Temp 350°C)
Specific Gravity	approx. 2.5
Hardness	approx. 6 degrees (mohs scale)
Young's Modulus	720,000 kg/cm^2
Poisson's Ratio	0.25
Average breaking stress	approx. 500 kg/cm^2
Weather resistance	no change

2. Research materials and methods

Two buildings with different types of glass were examined in this research (see Figure 5 and 6). The first is clear glass, the second is heat and solar-resistant glass. The clear glass has optimum transmission without shadow effect, also providing optimum natural light gain. The second type of glass is floating glass with heat and solar resistance. It is colored during manufacturing by adding coloring metals such as cobalt, iron and selenium to the raw glass. With the both buildings, the temperature of the outside air, the outer glass surface, the glass surface inside the building and the room temperature were measured.

WUFI-2D analysis is generally conducted when the object of research requires different heat and humidity responses. It is specifically required for complicated geometry, such as building corners, window locations and foundation connections, and when there are non-uniform sources/sinks of heat and moisture. In the study with WUFI-2D, Guimarãesa. S., et.all., 2016, revealed that the moisture transfer in the inner parts of the materials and construction building elements and components is of great importance for its behaviours characterization, especially for its durability, pathology, waterproofing, deg-

Table 2. *Technical characteristics of glasses (P.T. Asahimas Flat Glass, 2008).*

Type of Glass		Standard Thickness (mm)	Energy Characteristic				Light Characteristic		Shading Coefficient	Solar Factor [%]	U Value [W/m²k]
			Transmittance [%]	Reflectance [%]	Absorption [%]	Ultra Violet Transmission [%]	Transmittance [%]	Reflectance [%]			
Clear Glass		10	72	7	22	53	87	8	0.90	78	5.7
		12	69	6	25	50	86	8	0.87	76	5.6
		15	64	6	30	45	84	7	0.84	73	5.5
		19	59	6	35	40	83	7	0.80	70	5.4
heat and solar-resistant glass	Green	10	25	5	70	10	59	6	0.54	47	5.7
		12	21	4	74	7	54	6	0.51	44	5.6
	Grey	10	27	4	68	11	26	5	0.55	48	5.7
		12	21	4	75	8	20	4	0.51	45	5.6
	Dark Blue	10	29	5	67	19	42	5	0.56	49	5.7
		12	23	4	72	15	36	5	0.53	46	5.6
	Light Green	10	34	4	60	17	66	6	0.62	63	5.7
		12	30	4	65	13	62	5	0.59	50	5.6

Figure 5. *Building with clear glass facades as research object.*

Figure 6. *Building with heat and solar-resistant glass facades as research object.*

radiation appearance and thermal behaviour, causing changes with difficult performance prediction.

Arregi, B. & Joseph Little, 2016, used WUFI Pro and 2D to analyze the Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-walled Dwelling. There have not been many studies conducted on glass using WUFI-2D.

3. Results and discussion

During the measurement of research object, it can be seen that sunlight penetration into buildings with clear glass affected the room temperature significantly. At 11.00 to 15.00, the temperature of glass surface inside the building was higher than that outside the building, the glass absorbed the heat and transferred it into the building. It can be seen too that sunlight penetration into buildings with heat and solar

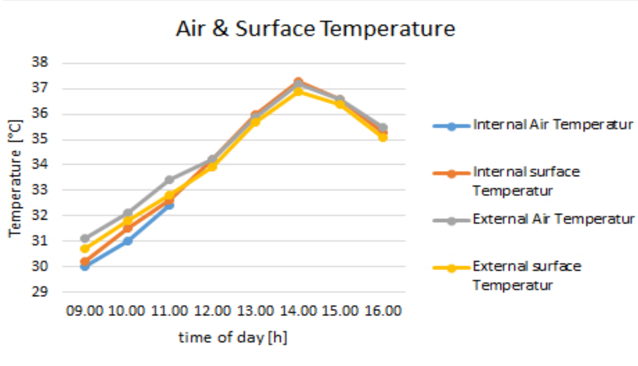

Figure 7. *Building with clear glass facades.*

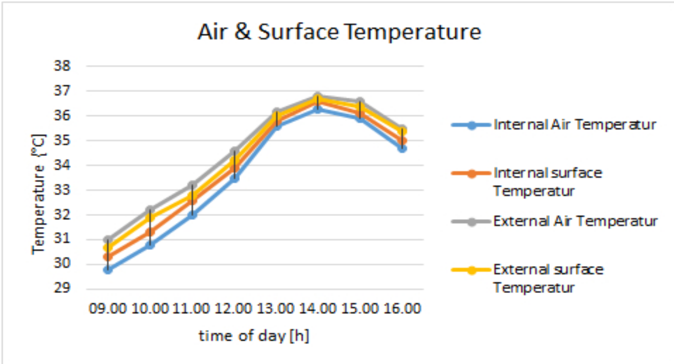

Figure 8. *Building with heat and solar-resistant glass facades.*

resistant glass facades, the influence of solar heat can be slightly retained by the use of glass. At 11:00 to 15.00, the solar heat can be slightly retained by the heat and solar resistant glass. As a result, the room temperature as shown in Figure 7 and 8 was affected.

During the observation of WUFI-2D Simulation, data input on glass materials was determined by the score differences on Specific Heat Capacity, thermal conductivity and porosity (Givoni, B., 1998). The results of data processing indicate a degree of density on temperature chart in Figure 9 and 10. Heat and solar-resistant glass has a higher density than clear glass. The heat transfer rate was affected as a result.

The results of the WUFI-2D Simulation regarding glass heat transfer show differences as can be seen below in Figure 11 & 12. With clear glass, the temperature of the glass surface outside the building ranges from 29.4°C to 39.2°C, while that inside the building reaches 39.2°C to 44.1°C. With heat and solar-resistant glass, the temperature of the glass surface outside the building ranges from 33.5°C to 39.2°C, while that inside the building reaches 39.2°C to 44.8°C.

The results of the above measurements, showed the same results as Ji-

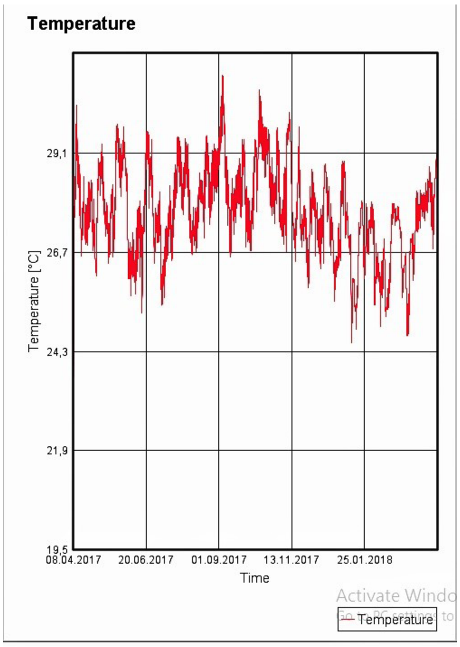

Figure 9. *WUFI-2D temperature chart with clear glass.*

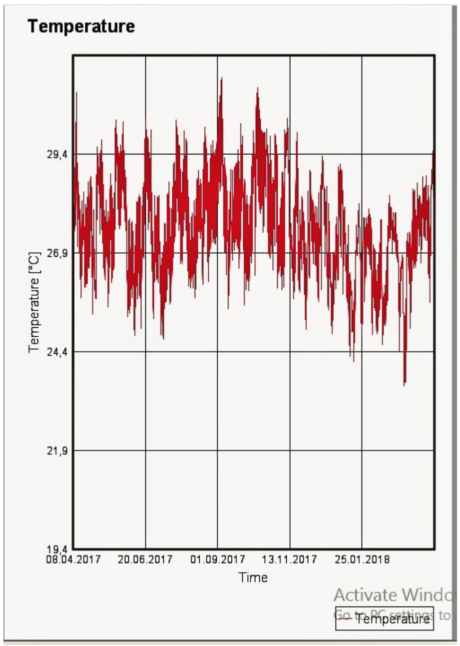

Figure 10. *WUFI-2D temperature chart with heat and solar-resistant glass.*

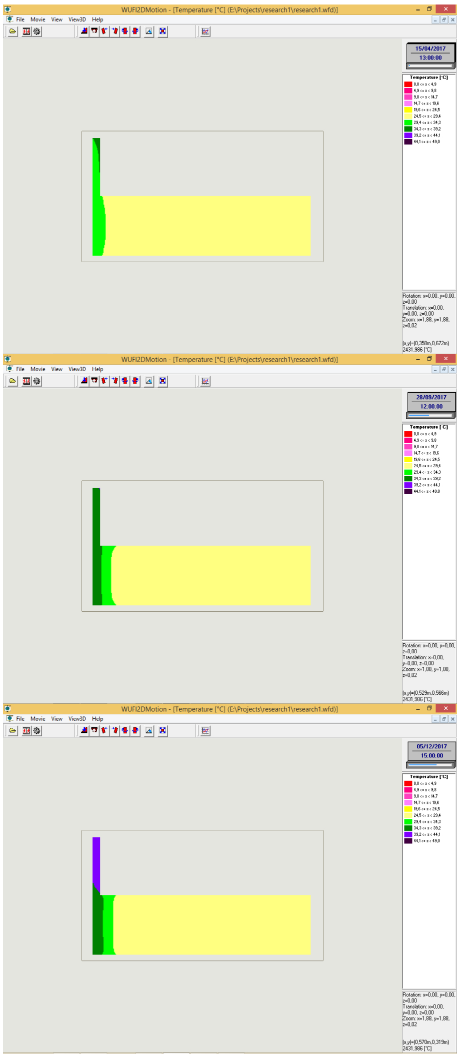

Figure 11. *Result WUFI-2D with clear glass.*

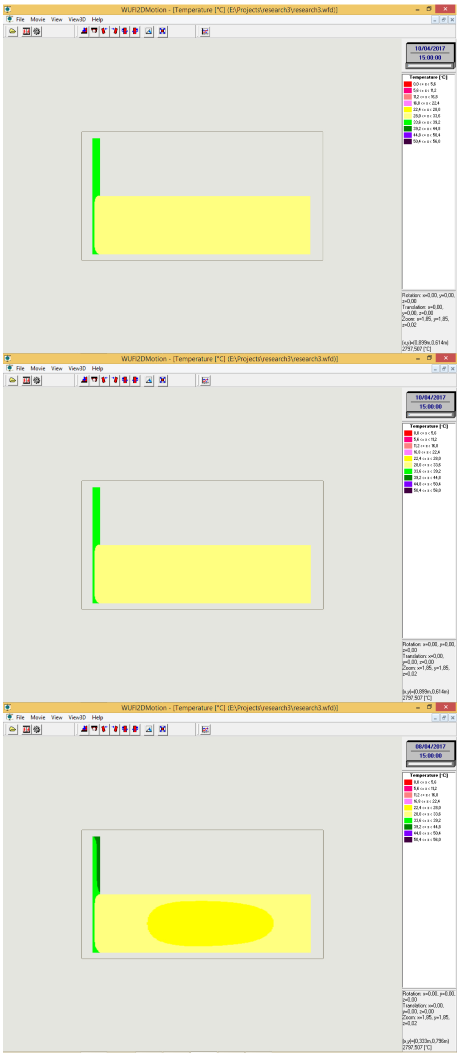

Figure 12. *Result WUFI-2D with heat and solar resistant glass.*

ru's research. Jiru,T.E., Yong-X. Tao and Fariborz Haghighat, 2011 study in heat transfer experiment on two different types of glass yields significantly contrasting results. To minimize heat transfer, glass facade can be treated differently. In his study, Jiru placed a ventilated air cavity between two glass facades, thus conserving energy for cooling.

The findings of this study support those of Manz. H., 2004. Factors influencing the heat transfer process in glass are as follows:

- the absorption value of clear glass (22 to 35 percent) is lower than that of heat and solar-resistant glass (60 to 75 percent);
- thermal transmittance (U-value) of insulating glazing unit is low.

Clear glass has a low absorption value; thus it cannot prevent heat transfer. This leads to an increased temperature on the inside glass surface and on overall temperature inside the building.

4. Conclusions

Sunlight penetration into buildings affects the room temperature significantly despite the use of heat and solar-resistant glass. The increase of heat in a building is directly proportional to the level of transmission, reflection and absorption of glass with absorption being the most important factor to decelerate the heat transfer into the building. The higher the absorption level, the less heat can transfer through the glass into the building.

Acknowledgements

This research was supported by the KAAD (Katholischer Akademischer Ausländer-Dienst) Scholarship and Technische Universität Darmstadt, Germany.

References

Arregi, B. & Little, J. (2016), Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-walled Dwelling, *Journal of Sustainable Design & Applied Research*, 4(1), 18-26.

Dananjaya, A., Priyatmono, A.F., & Raidi, S. (2013), Identifikasi Fasad Arsitektur Tropis pada Gedung-gedung perkantoran Jakarta (Studi Kasus Pada Koridor Dukuh Atas-Semanggi)- Identification of the Facade of Tropical Architecture in Jakarta Office Buildings (Case Study In Dukuh Atas-Semanggi Corridor), Surakarta, Universitas Muhammadiyah Surakarta, *Journal Sinektika,* 13(2), 125-135.

Givoni, B. (1998), *Climate Considerations in Building and Urban Design*, New York, John Wiley and Sons, Inc.

Glass, F. (2008), *Architectural Glass*, Jakarta, P.T. Asahimas Flat Glass

Gratia, E., & Herde, A. D. (2007), Greenhouse effect in double-skin façade, *Journal Energy and Buildings*, 39(2), 199-211.

Guimarãesa. S., Delgado, João M.P.Q., & de Freitas, V. P. (2016), Capillary Absorption in Monolithic and Multilayer Stone Walls: Numerical and Experimental Results, *International Journal of Fluid Mechanics Research*, 43(5), 404-417.

Jiru, T.E., Tao, Yong-X., & Haghighat, F. (2011), Airflow and heat transfer in double skin facades, *Journal of Energy and Buildings*, 43(10), 2760-2766.

Manz, H. (2004), Total solar energy transmittance of glass double façades with free convection, *Journal of Energy and Buildings*, 36(2), 127-136.

Purwanto, L.M.F. (2016), *Pengaruh Iklim terhadap Desain Bangunan di Semarang- Climate Influence on Building Design in Semarang*, Semarang, Research Paper, Universitas Katolik Soegijapranata.

Santoso, A.J., & Antaryama, I G. N. (2005), Konsekuensi Energi Akibat Pemakaian Bidang Kaca pada Bangunan Tinggi di Daerah Tropis Lembab - Consequences of Energy Due to the Use of Glass Fields in Tall Buildings in the Humid Tropics, *Journal Dimensi Teknik Arsitektur*, 33(1), 70-75.